A RECOMMENDED BUSINESS MODEL FOR INDUSTRY–ACADEMIA COLLABORATIVE SCIENCE & TECHNOLOGY RESEARCH CENTRES WITHIN AUSTRALIAN AND NEW ZEALAND UNIVERSITIES

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DEDICATION

I dedicate this to Yasanthi and Dinara

And to the cherished memories of my grandfathers

Joseph Martin Rosa (1929–1993) and S. Don Lawrence (1917–1999)

I was inspired by my great-grandfather, Mathew de Alwis (1903–1977), who was a lifelong diarist,

and throughout his professional life: a city councillor, a coroner and a businessman,

and a chief air-raid warden during the Second World War.

And in remembrance of my grandmother, Consie Mary Rosa (1929–1969)

Both of whom I never met, but wish I had…

Our greatest weakness lies in giving up.

The most certain way to succeed is always to try just one more time

– Thomas Alva Edison

ABSTRACT

Universities in Australia and New Zealand have a key role to play as knowledge generators and educators in the transition to the knowledge economy that is being driven by science and innovation. Research universities of the 20th century are transforming into entrepreneurial universities of the 21st century to deliver on missions around research, education and socio-economic impact. Industry–academia collaborative science and technology centres are increasingly becoming the vehicle of choice for universities to deliver knowledge economy impact in pursuit of this transition. However, without guidance through a business model framework for centres specifically designed for universities, these centres will continue to suffer from the lack of a robust foundation, which may render them non-viable beyond their initial seed funding. The objective of this research is to develop a business model recommended for industry–academia collaborative science and technology research centres within Australian and New Zealand universities.

This research has been performed with the researcher as a participant-observer conducting insider-led research across three Australian and New Zealand (ANZ) field-site universities from 2005 to 2016. The field-site universities were: (1) University of Canterbury in New Zealand; (2) Macquarie University in Australia; and (3) Monash University, also in Australia. This is in addition to a major longitudinal case study of an industry–academia collaborative research centre, the Electric Power Engineering Centre (EPECentre), at the University of Canterbury over 2005–2011.

The research has utilised a mixed-method research approach, which was qualitatively led using modified Grounded Theory. Furthermore, interviews have been conducted with senior representatives from industry, university and government in order to test the final research findings and to determine the feasibility of the recommended business model. In parallel with the research, the findings have been applied and validated in practice with 12 centres within ANZ, which has demonstrated the practical utility of this model.

The recommended business model is found to have four dimensions: (1) structure; (2) interactions; (3) finance; and (4) activity. The four dimensions have been visualised using the metaphor of a wind turbine generator (WTG), which enables simple cross-comparison between centres in universities. A WTG is also symbolic of sustainability in the modern world, given that the major challenge for many centres is to be viable beyond core establishment funding or when the operating environment poses challenges. Ultimately, the viability of a centre is determined by the value it delivers to stakeholders in industry, the university and government.

Indeed, business model theory has not been applied to industry–university research centres previously, making this research the first study of its kind for ANZ universities. With further research, the model developed has potential to be formulated into a weighted four-dimensional Centre Viability Index, for the purpose of assessing and improving new and existing industry–academia collaborative centres within ANZ. Overall, the success of industry–academia collaborative centres within ANZ universities can play a key role in the transition of ANZ into the knowledge economy and, in order to do that, these centres need a robust business model framework that has been customised and validated for ANZ.

ABBREVIATIONS AND ACRONYMS

4D	Four dimensional
A	Academia *or* academia-based centre
AG	Academia-based centre core-funded by government
ANZ	Australia and New Zealand
ARC	Australian Research Council
B2B	Business-to-business
B2C	Business-to-customer
BMI	Business model innovation
CEO	Chief Executive Officer
CRC	Cooperative Research Centre
CRM	Customer relationship management
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
CSR	Corporate social responsibility
CVI	Centre Viability Index
E	Education
ERA	Excellence in Research for Australia
ERC	Engineering Research Centre
EPECentre	Electric Power Engineering Centre
EPSRC	Engineering and Physical Sciences Research Council (UK)
G	Government
I	Industry *or* Industry Interaction
IA	Industry–Academia
I*A	Industry–Academia with a fee-for-service funding model
IAB	Industry Advisory Board
IAG	Industry–Academia–Government
IDC	Industry Doctorate Centres
IG	Industry-Government
I*G	Industry-Government with a fee-for-service funding model
IGB	Industry Governance Board
IP	Intellectual property
IPR	Intellectual property rights

ITRH	Industrial Transformation Research Hub
ITTC	Industrial Transformation Training Centre
I/UCRC	Industry/University Cooperative Research Centre
KE	Knowledge Economy
KM	Knowledge Management
KPI	Key performance indicator
KW	Knowledge Worker
MBIE	Ministry of Business, Innovation & Employment (NZ)
MMURC	Multipurpose Multidisciplinary University Research Centre
MoU	Memorandum of Understanding
NSF	National Science Foundation (USA)
OECD	Organisation for Economic Co-operation and Development
PBRF	Performance-Based Research Fund
PEET	Power Engineering Excellence Trust
PVC	Pro Vice Chancellor
QUAL	Qualitative
QUAN	Quantitative
R	Research *or* Resources
R&D	Research and Development
R_A	Applied Research
R_B	Basic Research
RE	Research and Education
REI	Research, Education and Industry Interaction
RI	Research and Industry Interaction
R_{UI}	Use-Inspired Research
S&T	Science and Technology
SME	Small to Medium-sized Enterprise
TEC	Tertiary Education Commission (NZ)
TTO	Technology Transfer Office
UC	University of Canterbury
WTG	Wind Turbine Generator

LIST OF PUBLICATIONS

The following academic publications have resulted from the research presented in this thesis, including a number of peer-reviewed conference papers, invited talks and a case study.

- Lawrence, J. D. and Bodger, P. S., "The Electric Power Engineering Centre 'New Zealand's Centre for Excellence in Power'", Electricity Engineers' Association (EEA) Conference, Auckland, New Zealand, 17–18 June 2005.

- Bodger, P. S. and Lawrence, J. D., "New Zealand's Centre for Excellence in Power: The Electric Power Engineering Centre", Invited paper, CIGRE, Electric Power Engineering Education Panel, Paris, France, 30 August 2006.

- Lawrence, J. D. and Bodger, P. S., "Practices of successful organisations applied to centres of excellence in New Zealand", IEEE International Conference on Management of Innovation and Technology, Singapore, 21–23 June 2006, paper A444, pp.146–150.

- Lawrence, J. D. and Bodger, P. S., "Two Cultures – Joint Success", Project Management Institute of New Zealand (PMINZ) Conference 2006, Christchurch, New Zealand, 5–6 October 2006.

- Lawrence, J. D. and Bodger, P. S., "Electric Power Engineers – Battling Supply and Demand", EEA Conference, Christchurch, New Zealand, 20–21 June 2008.

- Lawrence, J. D. and Bodger, P. S., "Electric Power R&D in New Zealand – 'Power Up or Power Down'", EEA Conference, Christchurch, New Zealand, 20–21 June 2008.

- Lawrence, J. D. and Bodger, P. S., "Project Management of an Industry–Academia Project of National Significance", Poster presentation, PMINZ Conference 2009, Christchurch, New Zealand, 21–23 October 2009.

- Lawrence, J. D., 2015, "An Industry-wide Collaboration Model for Innovation", Invited talk, Australasian Industrial Research Group (AIRG) Winter Meeting 2014, Melbourne, Australia, 26–27 August 2014.

- Lawrence, J. D., Sutalo, I., Morley, S., Hapgood, K., Patti, A, Skirbis, Z. and Bury, P., "Monash University – Chemicals & Plastics Innovation Network and Training Program", in: I. Watt, ed. *Case Studies on University–Business Collaboration: Review of Research Policy and Funding Arrangements.* Canberra: Australian Government Department of Education and Training, 2015, pp. 68–72.

Disclaimer: The opinions expressed in this research thesis are solely the opinion of the researcher and do not in any way represent the views of the Electric Power Engineering Centre (EPECentre), the University of Canterbury, Macquarie University or Monash University.

CHAPTER 1. INTRODUCTION AND BACKGROUND

The research presented in this thesis relates to collaborative models for industry–academia (IA) partnered science and technology (S&T) centres within Australia and New Zealand (ANZ) universities. The research undertaken is within the broad theme of industry, university and government collaboration, a topic that is a growing area of interest for developed and developing countries alike. This is especially relevant given the transition underway from an industrial economy to a knowledge-based economy (Etzkowitz, 2008). The human race has "no choice except a future based on science and technology" (Callaghan, 2009, p. 7).

1.1 INTRODUCTION

1.1.1 RESEARCH SCOPE

If investing for impact is aimed at intentionally driving measureable social and environmental benefit, then the importance of IA collaboration in impacting on society in the 21st century cannot be ignored, especially in the S&T domain (Financial Times, 2015a; Pertuzé, et al., 2010; United Nations Educational, Scientific and Cultural Organization, 1998).

This thesis describes a research study that commenced in 2005 to examine suitable models for S&T-based IA collaborative centres hosted and led by ANZ universities. To observe S&T centre formation and practice, the research study included fieldwork across three ANZ universities. The first was the University of Canterbury, a classical research university in New Zealand (NZ) founded in 1873. The second, Macquarie University, was established in 1964 in New South Wales, Australia as a "bold experiment in higher education" (Macquarie University, 2016). The third is ANZ's largest university, Monash University in Victoria, established in 1958.

The research findings present a structural blueprint, i.e. business model, for centres that can be applied to various S&T IA collaborations to generate new centres or improve existing centres within ANZ universities. The business model proposed envisions a framework that can give an IA centre hosted and led by an ANZ university a greater likelihood of being viable. This means the ability to have resilience over time and survive uncertainty in order to contribute value to the economy and society at large (Financial Times, 2015b). Ultimately, the viability of a centre is determined by the value it delivers to its stakeholders in the industry, the university and the government.

The focus of the research effort has concentrated on a university led and hosted model implied in centres within ANZ universities, where a centre is an integrated part of the host university with one or many industry partners and research collaborators, including other universities. Also, from the perspective of this study, the term 'centre' is synonymous with 'program', 'flagship', 'hub' and 'institute', where the term 'institute' can also imply a collection of centres under a single super centre. These are all terms that are used interchangeably within ANZ universities to refer to research centres.

In addition to involving industry and academia, the development of IA centres in universities also inherently involves government. The role of government can either be direct via funding for centre establishment or indirect through downstream research project funding. Government also has significant influences over the economic and social ecosystem within which IA centres must operate. Hence the three actors, i.e. academia, industry and government (Figure 1), all have some underlying drivers towards fostering IA centres within universities.

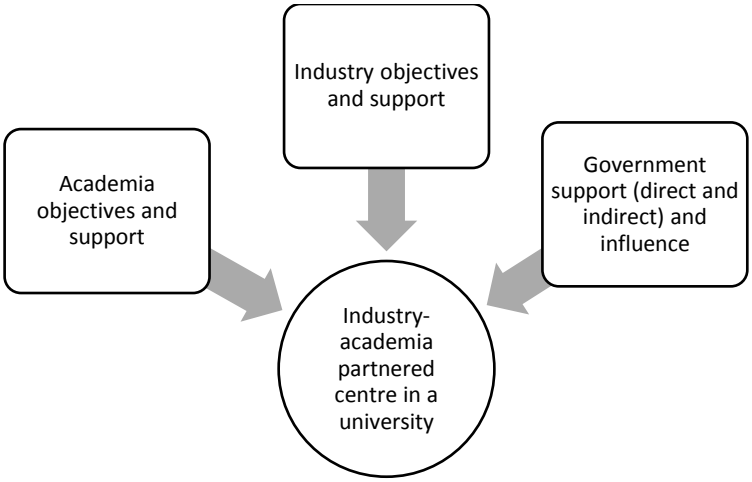


Figure 1 Segments that influences an industry–academia partnered centre in a university.

Government support plays an important role in facilitating IA collaboration. Governments are increasingly considering IA collaboration as high priority in order to build economic prosperity (Australian Government Department of Industry, Innovation and Science, 2015a). As nations look to survive in a knowledge-based economy, collaboration is becoming increasingly important around the world, particularly for publicly funded innovation systems (New Zealand Ministry of Business, Innovation & Employment, 2015).

Given the underlying impetus of ANZ governments in prioritising IA collaboration, this research project aims to provide a recommended business model to assist the configuration of various IA centres that can be deployed within ANZ universities.

The leading literature on the nexus of industry, university and government is through the Triple Helix theory (Etzkowitz, 2008; Leydesdorff, 2010). The literature describes the intersection of these participants within three spheres and stipulates that this intersection is the key to innovation and growth in the impending knowledge-based economy. The university is regarded as the leader in this theory, where it stimulates the development of industry and is the source of entrepreneurship and knowledge, in addition to its traditional role of education and research. The government plays the supporting role through funding and influence (Etzkowitz, 2008).

The distribution of various centre type combinations are shown in Figure 2, at the macro level, across the three domains of industry, academia and government, using a Venn diagram and herein referred to as the industry–academia–government (IAG) code. However, given the focus of this thesis on IA centres, the emphasis herein is exclusively on centres represented by the 'red stars' (Figure 2), as these are university and industry partnered centres. The 'red stars' refer to two types of IA centres:

(1) IA centres without direct (core) government funding (i.e. IA centres); and

(2) IA centres with direct government core funding (i.e. IAG centres).

Both of these are referred to as IA centres, unless otherwise stated.

The 'grey stars' (Figure 2) refer to industry–government (IG) centres, government-only (G) centres, academia–government (AG) centres and academia-only (A) centres. These types of centres are outside the scope of this thesis.

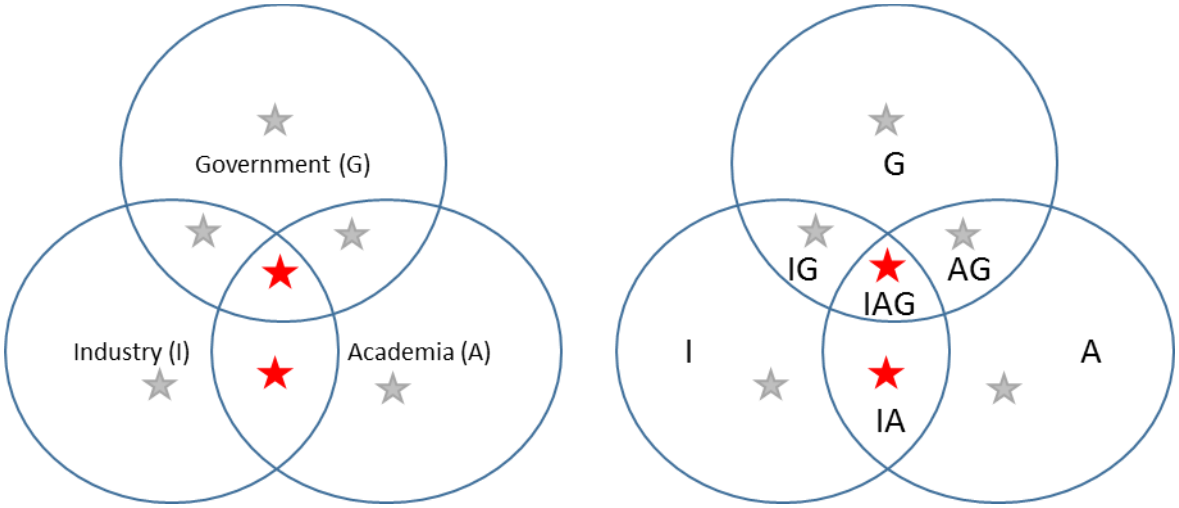


Figure 2 Distribution of centres across the Triple Helix, with centres represented by colour-coded 'stars' across industry, academia and government; where 'red stars' represent centres within a university in partnership with industry.

This thesis builds on the Triple Helix theory first presented by Etzkowitz and Leydesdorff (Etzkowitz, 2008; Leydesdorff, 2010) and the general literature on IA centres. It presents new insight and understanding of IA centres and for the first time demonstrates the applicability of business model theory to IA centres within universities.

The research has been conducted using qualitative research led mixed-method approaches, because these enabled an efficacious approach to studying the complexities of this topic within the real world, with human interactions in organisations, innovation and socio-economic considerations (Miles, et al., 2014). This research includes field-site observations by the researcher as an observing-participant conducting insider-led research from within the university context at three ANZ universities, over periods of time between 2005 and 2016.[1] In addition, a longitudinal case analysis was performed from 2005 to 2011 of an IA centre, the Electric Power Engineering Centre (EPECentre) at the University of Canterbury in New Zealand. This study has resulted in a number of publications over the course of the research.

1.1.2 RESEARCH ARCHITECTURE

Miles et al (2014) advocates the architecture of research in the form of a conceptual research framework.

Figure 3 is an overview map of the territory of research investigation which has been progressively elaborated over the course of the study as the data was collected and analysed.

This conceptual framework begins with existing literature on the knowledge economy and leading up to the Triple Helix (Etzkowitz, 2008; Leydesdorff, 2010). This guides the reader to the concept of an entrepreneurial university and the advent of centres within universities (one of the many vehicles of an entrepreneurial university) to deliver value to the knowledge economy. It also depicts the first-time convergence of business model theory with university research centre theory for the utility of this project.

[1] The PhD research has been conducted part-time over 2011–2016.

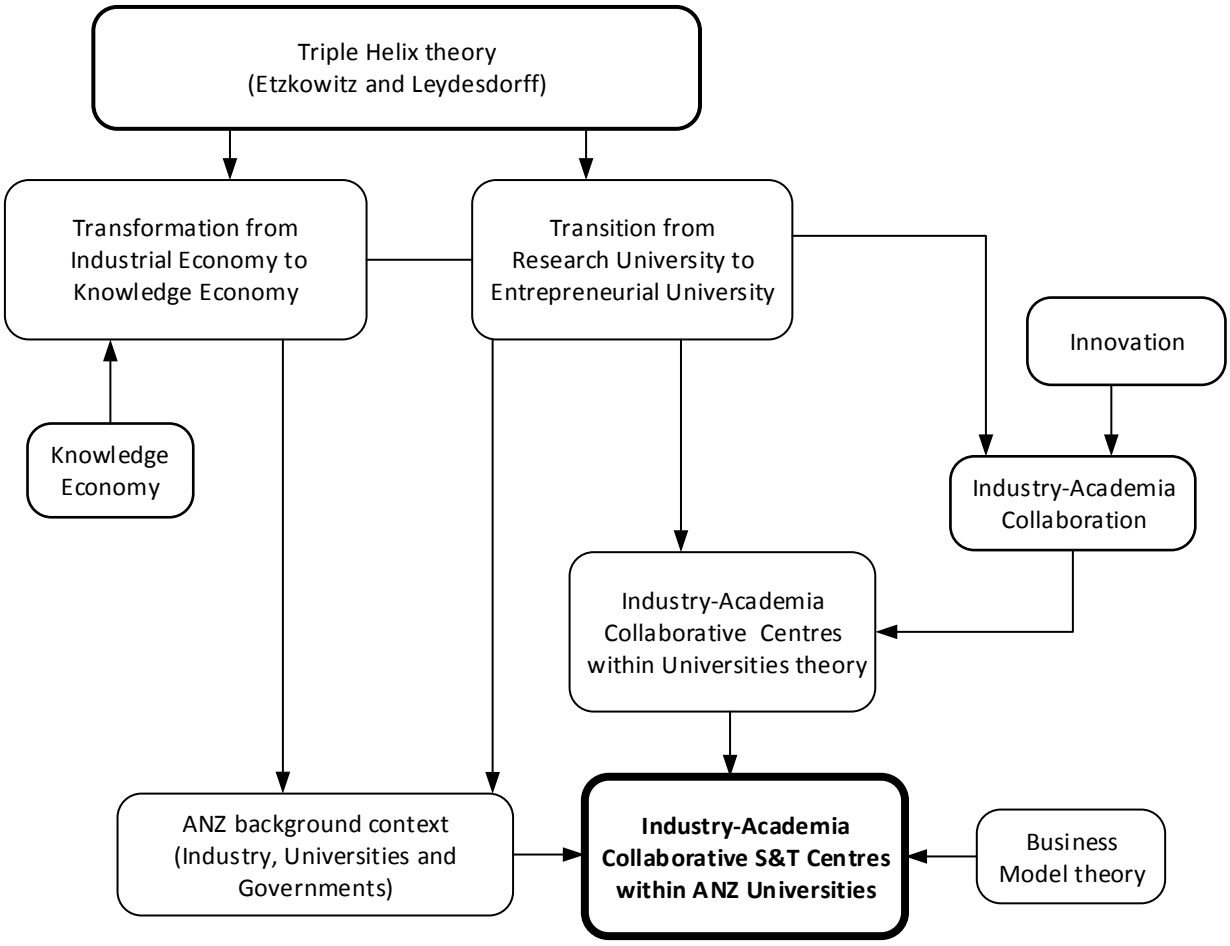


Figure 3 The conceptual research framework for the study of IA centres in ANZ universities.

1.1.3 OUTLINE OF THE THESIS

This thesis is organised into six chapters. Chapter 1 introduces the topic and describes the background setting of the research in ANZ, and Chapter 2 provides an overview of the main literature that underpins the broad subject area of the industry–government–university nexus described by the Triple Helix theory. This leads into the literature on the transition of research universities into entrepreneurial universities and ultimately to existing concepts of centre models and the theory of general business models and its applicability to IA centres.

Chapter 3 provides an overview of the research methodology and the method adopted, including the type of data and how it has been collected and analysed.

Chapter 4 presents the results and discusses the implications of findings, as well as the extraction of key findings towards the construction of the recommended business model.

Chapter 5 presents the recommended business model and the answers to the research questions, including the development and use of a wind turbine generator (WTG) metaphor. The WTG metaphor can be utilised in practice for identifying, comparing and categorising complex centre types, i.e. multidimensional aspects.

Chapter 6 concludes with overall findings and recommendations for practitioners in university, industry and government, and suggests areas for future research and where research impact has already occurred through this research output.

Prior to the literature review chapter, the next section of this chapter provides the background context of the ANZ operating environment, particularly with respect to ANZ universities, governments and industries, and the state of play with the economy.

1.2 BACKGROUND

The geographic isolation of Australia and NZ from other developed economies such as Europe, UK and the USA has ensured a close bond between the two countries. It also stems from a shared cultural history since the colonial era and a sense of regional identity (i.e. ANZ) that stems from the First World War, described as the Australian and New Zealand Army Corps (ANZAC) spirit.

Over one hundred years later, citizens of the two young nations are able to cross over and reside freely between the two countries (Immigration New Zealand, 2014; Australian Bureau of Statistics, 2002). The governments of the two countries are as closely allied as any two nations could be (Australian High Commission New Zealand, 2005) on everything from domestic policy through to defence and joint standards, i.e. Australian and New Zealand Standards (AS/NZS). Although the two nations do not share a common currency, economic ties are abundantly clear (Australian Government Productivity Commission, 2012).

Following is background on the ANZ operating environment for IA S&T centres within universities, with respect to demographics, innovation, management culture, universities and government.

1.2.1 ANZ DEMOGRAPHIC FACTORS

Some of the key demographic factors in ANZ that impact on IA S&T centres in universities are as follows:

- The population of Australia is 24 million (Australian Bureau of Statistics, 2016) and that of NZ is 4.6 million (Statistics New Zealand, 2016); Australia is approximately five times larger in population than NZ.
- Attitudes towards innovation, i.e. a tendency to adopt from overseas rather than to lead with innovation. Yet the people of ANZ are without doubt deemed to be innovators and have had a number of commercial global successes such as Cochlear in Australia and Fisher & Paykel in NZ (Australia and New Zealand Banking Group, 2015; Callaghan, 2009; Hodgson, 2000).
- Population considerations, e.g. ageing and socio-economic demographics.
- Transport, energy and health systems, availability of natural resources (e.g. abundance of coal).
- Environmental considerations, e.g. movement towards renewable energy.
- Philanthropy: The level of philanthropy in Australia remains a key challenge, especially for universities, when compared to overseas (Allen Consulting Group, 2007). It is assumed to be the case for the whole of ANZ. Coincidentally, university alumni are considered to be the primary source of donations for universities (Allen Consulting Group, 2007). In the USA, philanthropy is viewed as key to improving and maintaining the quality of universities (Vest, 2006).
- Political instability, i.e. three-year government cycles, where innovation and university programs are 'toyed with', leading to innovation funding vulnerability (Callaghan, 2009; Grattan, 2015).
- The quality of the university system and other research institutions (driven by size, funding, incentives and quality of research and knowledge output) is considered high (Australian Government Chief Scientist, 2015; Organisation for Economic Co-operation and Development, 2013).
- Industry collaboration with academia is considered poor (Australian Government Chief Scientist, 2015; Havyatt, 2015; Organisation for Economic Co-operation and Development, 2013).
- Industry competitiveness, e.g. global value chain integration, is considered low (Australian Government Office of the Chief Economist, 2015; Australia and New Zealand Banking Group, 2015).

- Partnering between small to medium-sized enterprises (SMEs), defined as employing fewer than 200 people, and large firms, defined as employing more than 200 people, is low (Organisation for Economic Co-operation and Development, 2013; Australian Bureau of Statistics, 2002).
- Proximity to Asia; ANZ is often referred to as the future 'food bowl' of Asia (Australia and New Zealand Banking Group, 2015).

Australia and NZ are both poor performers within the top 33 OECD countries (Figure 4) in terms of university or research institution collaboration with industry; Australia is 33rd out of 33 and NZ is 29th out of 33. In relative terms, Australia is placed last for university or research institution collaboration with SMEs and large firms, while NZ is relatively better at collaboration with large firms (Figure 5). NZ is also a smaller country, in terms of population and geography, which may be a factor in its universities and research institutions being more closely networked than in Australia's larger geography. These factors contribute to the operating environment for an S&T centre within an ANZ university; a comparison of key science and innovation related metrics between Australia and NZ is included in Appendix A.

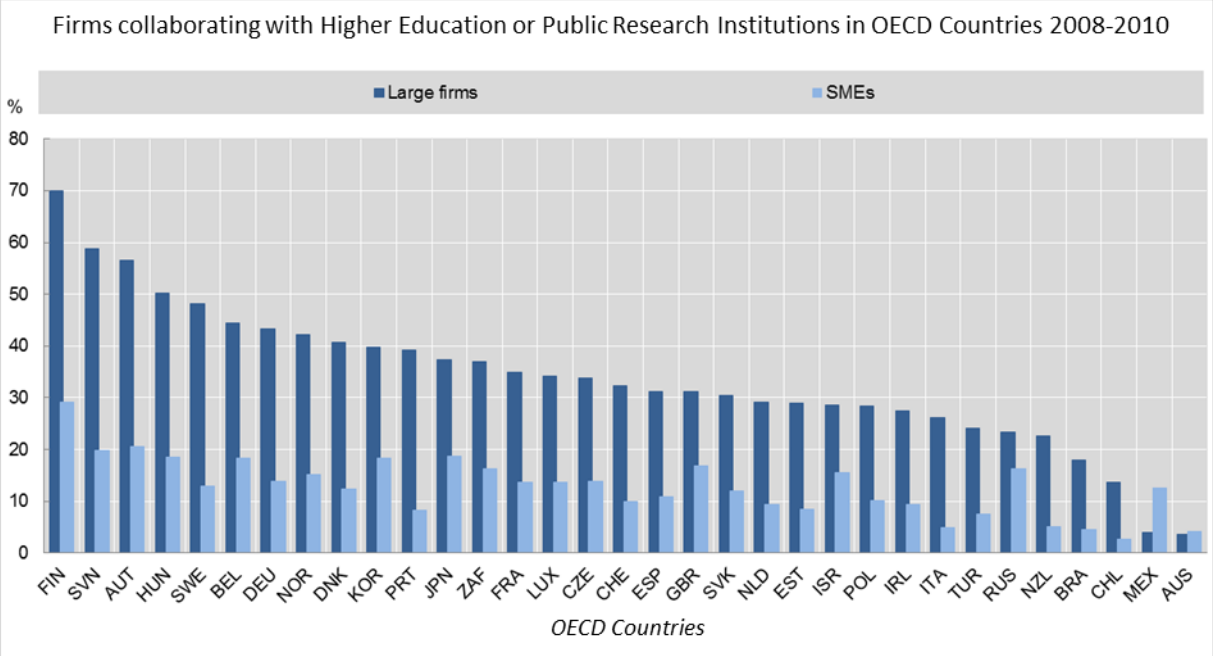


Figure 4 Firms collaborating on innovation with higher education or public research institutions, by firm size, 2008–2010, as a percentage of product and/or process innovative firms in each size category (Organisation for Economic Co-operation and Development, 2013).[2]

Furthermore, a significant consideration in ANZ is that the majority of organisations in industry are SMEs, as shown in Figure 5 (Australian Bureau of Statistics, 2010). This means that only 0.3% and 2.8% of industry are large firms in Australia and NZ, respectively. Therefore, approximately 99% of ANZ industry are SMEs with fewer than 200 employees and a mere 1% are large firms.

[2] Source: OECD, based on Eurostat (CIS-2010) and national data sources, June 2013.

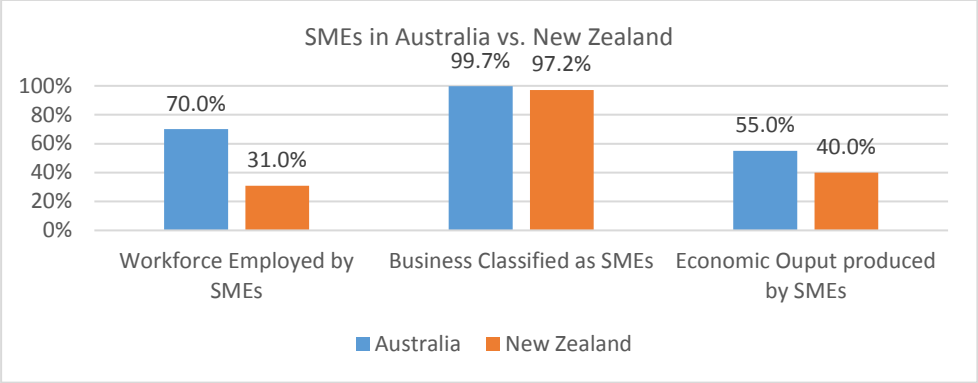


Figure 5. SMEs in Australia versus New Zealand: comparison of workforce population (adapted from sources (Creighton, 2012; Ministry of Economic Development, 2011; Small and Medium-Sized Enterprises Australia, 2011)).

1.2.2 INNOVATION IN ANZ

OECD innovation comparisons provide a snapshot of ANZ characteristics pertaining to innovation, business performance and collaboration for selected areas of interest, as shown in Figure 6 to Figure 8.

The industry characteristics for innovation and collaboration in ANZ (Figure 6) indicate that industry in both Australia and NZ is less than 2% for cooperation arrangements with universities, whereas business-to-business cooperation is 16.5% on average for ANZ. Both countries also have a less than 50% innovation rate, i.e. the percentage of innovation-active businesses in the country, which may be linked to the lack of collaboration with universities.

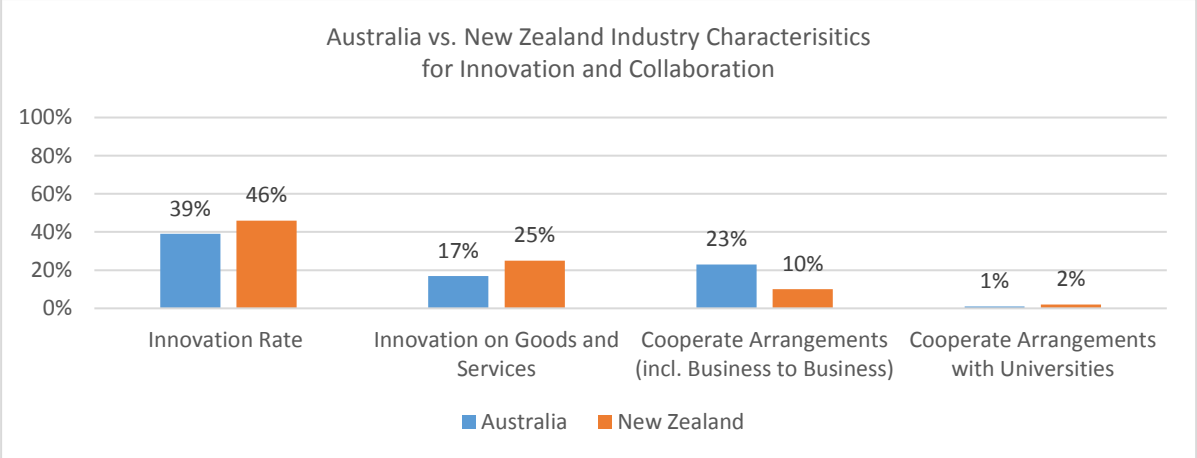


Figure 6. Australia versus New Zealand industry characteristics for innovation and collaboration (adapted from source: (Organisation for Economic Co-operation and Development, 2013)).

In comparison to OECD top performers (Figure 7), ANZ is 13% behind on university–industry collaboration, while company spending on R&D is 24% less than in the leading countries of the world. The availability of scientists and engineers is also 24% behind in ANZ. The quality of research institutions (including universities) in ANZ is the most important of all the other measures relative to the context of innovation, at only 10% below the top OECD countries. These in combination are all factors that impact on IA centres within ANZ universities, as they shape industry appetite, government motivation and university strategy.

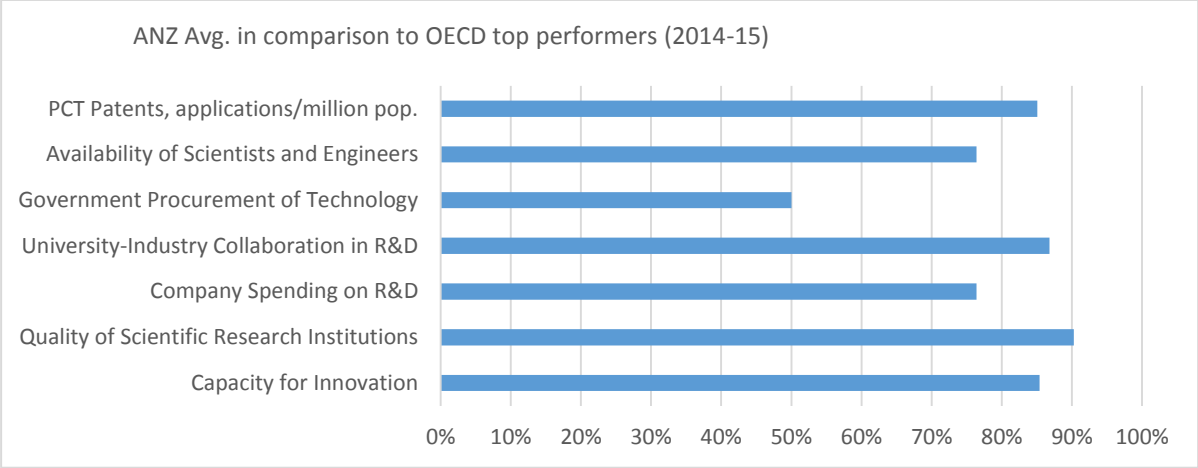


Figure 7 OECD innovation comparisons: ANZ average in comparison to OECD top performers (adapted from source: (Organisation for Economic Co-operation and Development, 2013)).

A comparison of problematic factors for conducting business in ANZ is shown in Figure 8, where infrastructure, government bureaucracy, capacity to innovate, access to finance and workforce education are emphasised as key problem areas. These in turn impact on IA centres within universities, pertaining to research infrastructure, government support for IA collaboration, willingness of industry to collaborate and lack of finance (e.g. venture capital funding for innovation). This also highlights opportunities for cultural change within ANZ, where universities could potentially play a greater role in professional education and training (e.g. upskilling of industry personnel) as part of IA collaboration.

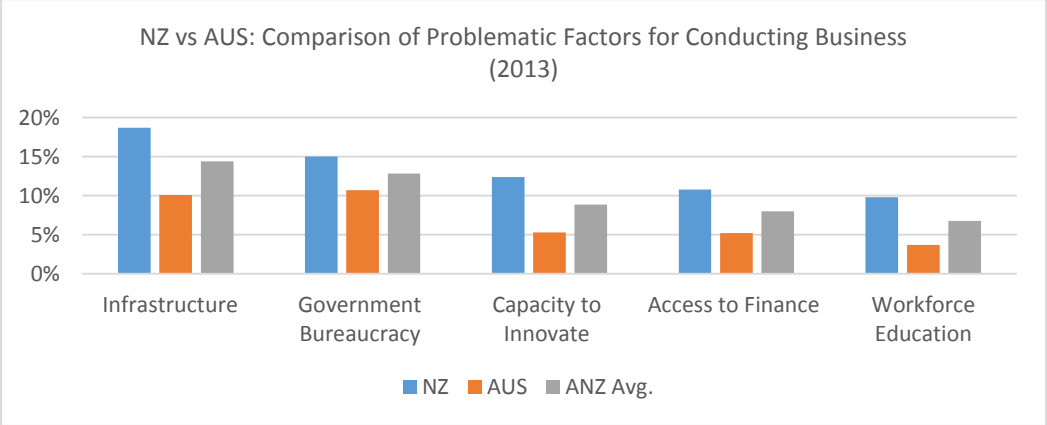


Figure 8 New Zealand versus Australia: comparison of problematic factors for doing business (adapted from source: (Organisation for Economic Co-operation and Development, 2013)).

1.2.3 ANZ MANAGEMENT CULTURE

Management culture in ANZ is a key factor in shaping the future as it transitions to the knowledge economy. The Australian Institute of Management (AIM) and the New Zealand Institute of Management (NZIM) conduct routine surveys using the same capability index standard to gauge management capability in Australia and NZ, respectively. These survey results are referred to as the Australian Management Capability Index (AMCI) and New Zealand Management Capability Index (NZMCI), correspondingly. Using data sourced from these indices, the AMCI results have been found to be comparable to the NZMCI results (Australian Institute of Management, 2015a; New Zealand Institute of Management, 2013), which suggests that either index may be a useful surrogate for describing ANZ management culture as a whole.

Selected AMCI data (as an indicator for ANZ management culture) relevant to innovation, collaboration and governance is shown in Figure 9. According to this, the executive level, i.e. Chief Executive (CEO) or Managing Director level, has significantly more interest in strategy and vision, organisational capability, application of technology and knowledge, and innovation than any other levels of management in ANZ industry. This suggests that IA centres should ensure engagement at the executive level for a deeper level of IA collaboration.

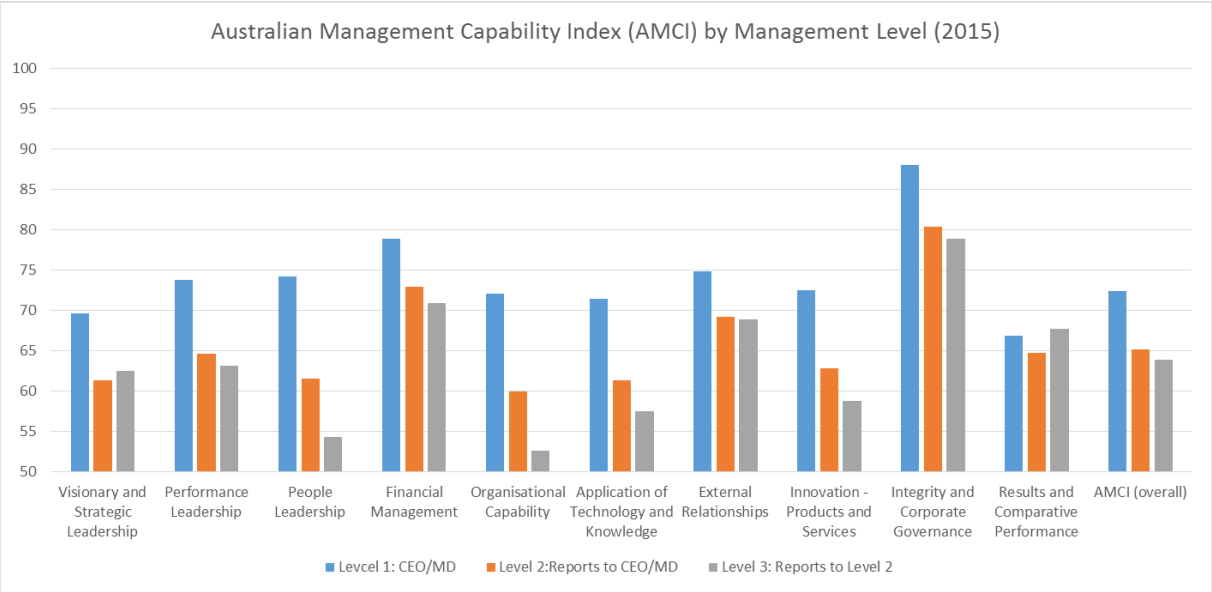


Figure 9 Australian Management Capability Index (AMCI) comparison by level of management (adapted from source (Australian Institute of Management, 2015b)).

1.2.4 UNIVERSITES IN ANZ

There are 50 universities in ANZ (42 in Australia and 8 in NZ), of which 47 are public universities (i.e. government is the major stakeholder) and 3 are private universities (subsection 4.1.1, Table 9).

A notable description of ANZ university culture can be summarised with the following statement, which was made during an interview (published on 1 May 2014) on university competition versus the public good by the vice chancellor of an Australian university:

> Universities are hybrid organisations, straddling the public and private spheres. We are creatures of (mainly) state legislation, substantially (but not wholly) supported by Commonwealth funding, often engaging in competitive behaviour … We compete with one another (and globally) for the best students, for excellence in research, for the most qualified staff and, ultimately, for status. Nevertheless, when eyeing off one another's TV adverts, or pondering a fresh branding exercise, we mustn't undervalue our more traditional 'public good' role. (Professor Peter Lee, Vice Chancellor, Southern Cross University, Australia (Lee, 2014))

There is plenty of competition between universities to attract industry partners (especially financial partners) in order to have impact, build reputational kudos, secure research funding and create job avenues for graduates. Research centres can play a pivotal role in this and are often seen as externally facing flagships for universities.

There is also passive competition across departments and faculties within a single university. According to a business development manager at one of the field-site universities, "departments and research groups are like SMEs" while another described the various research groups as "butterflies flying in formation".

This implies that research groups have their own ambitions and interests, and so have a tendency to pursue their own interests first and foremost, irrespective of the corporate directives of a university per se. This is the observed culture within universities, typically described as 'academic freedom', which is different to industry corporate culture, where the corporate directives go top down. People choose an academic career path to have this freedom, even if it means less remuneration in public universities compared to industry. Universities are somewhat bottom up and top down, both at the same time, bottom up being more dominant in practice.

Collegiality is also a key factor within university culture, where academic staff have been observed to often be dissatisfied when non-inclusive decision-making occurs in the university. Another dynamic that has been observed is the segregation between academic and non-academic staff members e.g. two parallel streams of employees, academic staff and general staff, with two separate remuneration streams and avenues for progression (University of Canterbury, 2016a):

> It is time that government and universities recognised that their staff are not exclusively academic. For universities to run well and for the quality of learning, teaching and research to improve into the future, the skills, knowledge and contributions of all staff, both academic and general, need to be recognised and developed ... the emergence of a quasi-academic staff group suggests previously accepted academic and general staff boundaries might be blurring … we have a real opportunity to move beyond the old stereotypes and look to the future. (Conway, 2002)

This is an issue for centres that want to recruit high-quality industry-type staff as directors, managers or hybrid academics (section 4.7), with respect to salaries and employment conditions that are comparable to industry roles.

According to the government definition of research in ANZ (Australian Government Department of Education and Training, 2016; Tertiary Education Commission New Zealand, 2016), a university typically has research performance metrics that capture total research income, postgraduate student supervision and publication statistics. However, measuring is done after the fact. Ultimately, it is about converting the research "outputs into economic and societal benefits" (Australian Academy of Technology and Engineering , 2016, p. 4).

A deeper analysis of ANZ universities is included in Chapter 4 with respect to IA collaboration and centres. However, the rationale for coupling Australia and NZ as ANZ for this research can be summarised as follows:

- The ability to find empirical evidence in ANZ at the University of Canterbury, Macquarie University and Monash University, i.e. the observations are verifiable at the field-site universities, rather than purely theoretical.
- The OECD performances of Australia and NZ are comparable when it comes to poor IA collaboration (Figure 4) and low levels of knowledge flow and commercialisation (average or below average performance), as well as the high quality of the science base (Appendix A).
- Both Australia's and NZ's shared British history, leading to the establishment of public universities at around the same time period and similar policy frameworks for higher education (e.g. the Performance-Based Research Fund (PBRF) in New Zealand, which is equivalent to the Excellence in Research Australia (ERA) and block grants in Australia), the strategic push for IA collaboration at ANZ universities (as evidenced by strategic plans at the University of Canterbury, Macquarie University and Monash University), and comparable government rhetoric for innovation in both countries (national innovation policy statements, e.g. R&D tax credit incentives for IA collaboration).
- The similar management cultures in Australia and NZ, as indicated by the Management Capability Indices for both countries, respectively.

- 99% of firms are SMEs and 1% are large firms in both Australia and NZ, and many Australian and NZ medium to large firms operate as ANZ companies across the two geographies.

From the background analysed, it was logical to combine Australia and NZ as ANZ for the purposes of the research topic, given the similarities in demographic factors, management culture, and university practices. Furthermore, the likenesses in culture, socio-economic drivers, and the strategic priorities and approaches (policies) of universities and government were significant. Beyond the ANZ context for the research, the next chapter presents a literature review on the topic (Chapter 2).

CHAPTER 2. LITERATURE REVIEW

An IA collaborative S&T centre within a university is indeed an organisation, a not-for-loss business, with its own objectives, stakeholders, resources and structure. Many centres either aim to be, or are expected to be, viable beyond the initial establishment phase by their stakeholders and funders as a return on investment (ROI). This research study is aimed at developing a recommended business model for industry–academia (IA) collaborative science and technology (S&T) centres within ANZ universities.

This literature review chapter is structured into four parts that follow a top-down systematic view of the research field, as shown in Figure 10:

1) Part A: Knowledge Economy to Entrepreneurial University
2) Part B: Science & Technology Research Centres
3) Part C: Centre Models and Scope for Future Research
4) Part D: Application of Business Models to Centres

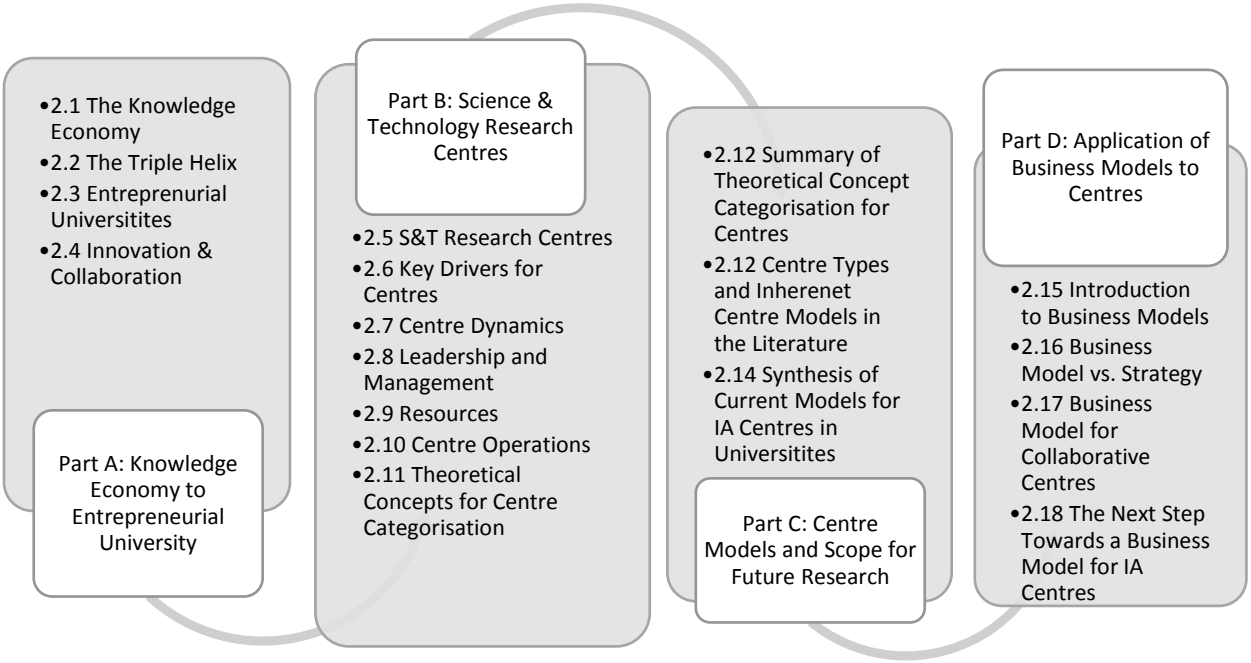


Figure 10 The structure of the four-part literature review.

Part A: Knowledge Economy to Entrepreneurial University

2.1 THE KNOWLEDGE ECONOMY

Knowledge is considered one of the key sources of growth for the global economy and the coining of the term 'knowledge economy' (KE) reflects this (World Bank, 2004). "A knowledge economy is one where organizations and people acquire, create, disseminate, and use knowledge more effectively for greater economic and social development" (World Bank, 2004, p. para 1).

Innovation is regarded as the application of knowledge (Australian Government, 2013). Moreover, through innovation, knowledge can be utilised to optimise the performance of products, processes and services (Matthews, 2003). In fact, "knowledge and innovation are inseparable from each other – they drive economies around the world" (Australian Government, 2013, p. para 1).

The key to innovation and growth in a knowledge economy is collaboration between industry, university and government (Etzkowitz, 2008; Lundequist & Waxell, 2010; Styhre & Lind, 2010; Leydesdorff, 2010). In contrast, the interplay between industry and government was the key element of the industrial economy (Etzkowitz, 2008; Drucker, 1999; Brinkley, 2006; Bang, et al., 2010). In a knowledge economy, there is recognition of close linkages between S&T, innovation, education and lifelong learning for the purposes of economic growth, social development and competitiveness (World Bank, 2004).

The KE accompanies globalisation with industrial value chains across the world, improvements to information communication technology (ICT) and the rise in high-value-added services, in parallel with a growing divide between countries with low and high costs of labour and improvements to global standards of living (Brinkley, 2006; World Bank, 2004). Consequently, it also leads to greater autonomy for workers and promotes highly skilled and highly paid jobs, but also creates inequality on the other end of the spectrum for those who are not directly engaged in knowledge work (Powell & Snellman, 2004).

The framework required to transition to a KE consists of (World Bank, 2004):

1) platforms that support new and existing knowledge and encourage entrepreneurship
2) an educated and skilled workforce
3) an efficient innovation system of research centres, universities, industry, think tanks, consultants and other related organisations
4) ICT infrastructure to facilitate the dissemination of knowledge.

The emergence of the KE is also impacting on global employment markets with their hunger for university-educated knowledge workers (Brinkley, 2006). Consequently, measures of research and development (R&D) alone for a country do not capture the overall innovation effort (Brinkley, 2006). For example, a multinational company owned in one country may perform a large portion of its R&D in another country as a foreign direct investment which is not recorded in the home country as R&D activity, even though the benefits of this R&D eventually transfers back to the home country over a longer period of time (Brinkley, 2006).

Nevertheless, there is an opposing view that questions the very existence of the KE on the basis that society has always been progressed by innovation and knowledge, just at a more rapid pace now than in the past (Brinkley, 2006). Hence, Brinkley (2006) supports the view that the KE is perhaps simply a soft gear change, rather than a sharp jump. However, there has been a fundamental shift to knowledge and information for the production of wealth (Bang, et al., 2010):

> The transition towards a knowledge economy is characterised by a transition away from the majority of work being occupied with producing and distributing things, to the majority of work being occupied with applying knowledge to knowledge. (Bang, et al., 2010, p. 617)

The management guru Peter Drucker is in fact considered to have founded the field of knowledge management (KM) to underpin the transition to the knowledge economy and consequently he coined the term 'knowledge worker' (KW) in 1959 (Peters, 2010). He argues that knowledge by itself is not productive and only becomes so when fused together to produce something that delivers business value (Bang, et al., 2010). The people who produce knowledge and the fusing of knowledge are knowledge workers, and the discipline of managing those processes is knowledge management (Peters, 2010). According to Drucker, "the most valuable asset of a 21st century institution (whether business or non-business) will be its knowledge workers and their productivity" (Drucker, 1999, p. 79).

Drucker (1999) considers the principles of manual-work productivity developed by Frederick Winslow Taylor (1856–1915) the foundation of KM, with concepts such as "workers be paid according to their productivity" (p. 81), i.e. compensated for productive output rather than for hours worked. This is where the focus has shifted to achieving results and continuously measuring performance (Bang, et al., 2010). Moreover, Frederick's legacy has led to modern 'scientific management' and 'industrial engineering' as they are known today (Drucker, 1999). In fact, Drucker (1999) predicts that the competitive advantage for a country's future is in its young people who are trained and educated for knowledge work. In the future, being able to attract and retain KWs will be a continuous challenge (Drucker, 1999; Jayasingham & Yong, 2013).

A parallel term used for the KE is the knowledge society (KS), from a societal rather than an economic perspective (Peters, 2010). According to Peters (2010), from the 1970s to the 1990s a diverse range of perspectives emerged, e.g. sociology, that further elaborate on the definition of KE and have subsequently led to closely linked terminology such as the 'learning economy', 'creative economy', 'open knowledge economy' and 'knowledge-based economy' (Leydesdorff, 2010; Peters, 2010).

Leydesdorff (2010) points out that there are two types of knowledge, codified knowledge and tacit knowledge, the former being knowledge that can be written down and the latter being know-how that is acquired on the job and grows through experience (Brinkley, 2006). The production of knowledge through organised R&D within innovation systems has become a standard function of the economy (Leydesdorff, 2010). This is essentially a move from being resource focused to being knowledge focused, where the economic mix is moving from resources, labour and capital to a mix of knowledge, labour and capital.

2.2 THE TRIPLE HELIX

"In the knowledge economy, growth and job creation depend on our ability to generate and exploit intangible assets such as brands, human capital, and design. Here, innovation is the primary driver of value" (Reid, et al., 2010, p. 3). In the model for the KE developed by Etzkowitz and Leydesdorff, which is called the Triple Helix, university, industry and government are defined as the main participants in the KE (Etzkowitz, 2008; Leydesdorff, 2010). This perspective can also viewed as an innovation eco-system, which comprises "organisations, institutions and linkages through which the economy create new value in the form of products and services" (Reid, et al., 2010, p. 3). Therefore, there is a need to facilitate better connection between the knowledge generators (universities) and the implementers of that knowledge (industry). This is also of interest to governments as a means to advance nations.

The Triple Helix model portrays the university as the lead institution in the KE, ahead of industry and government, because of the constant influx of human capital, i.e. students (Etzkowitz, 2008;

Leydesdorff, 2010). In Etzkowitz's (2008) view, industry is the main agent for the delivery of products and services, while government plays a key facilitation role for both the industry and university, as well as providing oversight and rules of engagement within the KE. The Triple Helix is represented by three concentric interwoven circles in the form of a Venn diagram (Figure 11). It depicts the interaction and co-dependency between each sphere in the KE: industry, university and government.

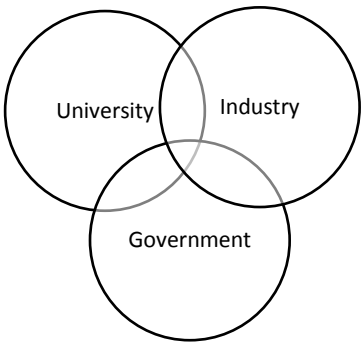


Figure 11 The Triple Helix theory Venn diagram with three concentric interwoven circles for industry, university and government (Etzkowitz, 2008).

The interactions of the concentric circles in the Triple Helix theory have given rise to what is referred to as the 'entrepreneurial university'. However, universities are said to be in transition from research universities to entrepreneurial universities. The original research universities, which are referred to as 'ivory-tower' universities, represented a focus on two missions, research and education, while the entrepreneurial universities have added a new third mission, the mission of societal and economic impact into the lexicon of the university (Etzkowitz, 2008).

A parallel philosophy to the Triple Helix is Mode 1 to Mode 2, where Gibbons (2003) presents a view that academia has transitioned from Mode 1 to Mode 2. In Mode 1, the government was the primary funding source for university research and outputs were disseminated as a public good via publication (Dooley & Kirk, 2007). Consequently, under Mode 1 research activity was scattered, as the mode of knowledge dissemination was via publication and this took time. The discovery process was also slow to get findings verified by other universities or industry, and interaction between university and industry was trivial since research was not driven with an end-use application purpose. However, this led to greater academic freedom to pursue individual research paths, resulting in an endless cycle of discovery research with minimal industry interaction (Dooley & Kirk, 2007).

Mode 2, on the other hand, is more akin to the Triple Helix theory, where there is an emphasis on applied research, technology transfer and industry collaboration (Dooley & Kirk, 2007) – a more entrepreneurial approach. Gibbons (2003) suggests that there has been a shift from Mode 1 to Mode 2 in academia, while Etzkowitz (2008) and the Triple Helix followers[3] argue that Mode 2 is the original form of the university to begin with and now there is a return back to its origins (Etzkowitz, 2008).

The Triple Helix is thought to have two key measures of success: (1) the rate of knowledge development; and (2) the speed of knowledge transfer and exploitation (Dooley & Kirk, 2007). Consequently, this has implications for universities in ANZ, which too are in transition towards becoming entrepreneurial universities, as evidenced by the strategic objectives set by ANZ universities (University of Canterbury, 2015; Macquarie University, 2015; Monash University, 2015), and thus an appetite for IA collaboration is growing, including increasing interest in the formation of IA centres.

[3] The researcher is a member of the global Triple Helix Association: https://www.triplehelixassociation.org/

2.3 TRANSITION TO ENTREPRENEURIAL UNIVERSITIES

Etzkowitz (2008) argues that the transition from research universities to entrepreneurial universities, with increased interaction between university, government and industry, has paved the way for the venture capital industry, the incubator and the concept of a science park. Furthermore, he refers to transformations within the university sector as having spawned concepts such as collaborative research centres, technology transfer offices (TTO) and industry engagement offices. Overall, the interactions between industry, university and government have been ramping up since World War Two (Etzkowitz, 2008; Gray & Walters, 1998).

The first entrepreneurial university was MIT (Massachusetts Institute of Technology), soon followed by Stanford University (Etzkowitz, 2008). In the Triple Helix, professors, engineers, scientists, businesspeople and government bureaucrats can all be entrepreneurs in their own ways to contribute individually or collectively to the KE. The university by default becomes the entrepreneurial hub for the KE, where the university sector adapts to produce and transfer out knowledge in cohesion, including the commercialisation of intellectual property (IP), utilisation of knowledge through consulting, and entrepreneurship education. This is in addition to conducting a mix of applied and basic research (Etzkowitz, 2008). Ultimately, this can lead to regional development through innovation clusters, incubators and collaborative (local and global) networks around the entrepreneurial university (Etzkowitz & Klofsten, 2005).

According to Dzisah and Etzkowitz (2007), some universities, such as Newcastle University in the UK, have gone further and adopted the 'professors of practice' concept, where industrialists join the ranks of the university to serve as role models for academics and to lead translational activities, entrepreneurship and regional development through innovation (Dzisah & Etzkowitz, 2007).

The entrepreneurial university is a dynamic concept, so researchers can shift between conducting pure basic research and working on innovative ideas for commercialisation (Styhre & Lind, 2010). Nevertheless, there are some critics, such as Washburn in her book *University Inc.: The Corporate Corruption of Higher Education* published in 2005, which warns that "the triple-win strategy of university–industry partnerships … comes at the expense of the university's core values" (Krimsky, 2005, p. 63). In Washburn's view, scientific integrity and objectivity can be compromised by commercial interests (Krimsky, 2005). In this debate, the adoption of applied research in the university context "constitutes a betrayal of the fundamental values of autonomy and independent inquiry" (Gibbons, 2003).

Etzkowitz (2008) believes that "the implications of the triple helix transcend innovation and influence the way we work and interact". For instance, government plays a key role in incentivising university–industry interaction, including changes to patent law and provision of public funding for innovation and R&D. However, some pivotal legislation was passed in the USA that has had impact across the world: the Bayh-Dole Act of 1980. For the first time universities were allowed to own intellectual property (IP) created through government-funded research. This led to a global explosion of university spin-out companies, university technology licences and IP assignments, thus spurring the birth of new industries, such as biotechnology and nanotechnology, seeded by private and public venture capital and further catalysed by the spread of the internet for dissemination of knowledge.

The key transformation within academia itself, argues Etzkowitz (2008), has been the adoption of the new third mission, which has energised universities to play an active role in pursuing societal and economic impact. The "entrepreneurial university is not a radical new form of university, a form of venture representing a rupture with the past, but is instead very much a matter of maintaining old 'academic virtues while simultaneously contributing to more practical interests'" (Styhre & Lind, 2010, p. 923).

Overall, this shift encourages universities to find new ways to collaborate, such as through the development of university–industry collaborative centres, particularly in the S&T realm, with and without government support. Together, centres, incubators and science parks are three key forms of collaboration in future industrial innovation realms. Literature on the entrepreneurial university concept suggests that there is a growing need for IA centres within universities, since collaborative research centres are one of the hallmark vehicles of the entrepreneurial university, in train with the transition to a KE, thus necessitating the need for boundary spanning, i.e. between the Triple Helix actors of industry, academia and government (Figure 11).

2.4 INNOVATION AND COLLABORATION

Innovation in the context of entrepreneurial universities involves collaborative R&D. This innovation activity can be defined as the discovery and application of knowledge pertaining to products, processes and services (Lawrence & Bodger, 2008b). Nevertheless, industry executives approach this as a trade-off between R&D expenditure and ROI (Lawrence & Bodger, 2008b). Lawrence and Bodger (2008b) refer to a study carried out by the Boston Consulting Group across 52 countries, where it was found "that only 46% of executives were satisfied with ROI on R&D, even with 6% ranking the importance of R&D activity within their organisation's top three strategic priorities" (p. 6).[4]

Industry reacts to downturns in the economy by reducing expenditure on R&D (Lawrence & Bodger, 2008b). Another ongoing concern in industry practice is the management of the 'knowledge gap', when people retire or change jobs and take their knowledge assets with them (Lawrence & Bodger, 2008a). Coincidentally, both talent retention and attraction within industry are major concerns in terms of managing knowledge capability, especially in the context of industry–university collaboration, where universities train and produce the talent pool for industry (Lawrence & Bodger, 2006a; Lawrence, et al., 2015; Lawrence & Bodger, 2008a).

According to Verganti (2009a), innovation can have three strategic approaches: (1) market-pull; (2) technology-push; and (3) design-driven or design-push. These innovation strategies are presented in Figure 12, where:

- market-pull is end-user centred, underpinned by socio-cultural edicts and incremental improvement
- technology-push is discovery research driven as a radical improvement or a disruption to existing technology; and
- design-driven is "propelled by a firm's vision about possible breakthrough meanings and product languages that people could love" (Verganti, 2009a, p. 56), which is closely coupled to technology-push. For example, the introduction of the Sony Walkman® is an example of design-driven innovation, where 'portable music on the go' became the new 'meaning' (Verganti, 2009a).

[4] All references to papers by Lawrence are publication outputs of the researcher's PhD studies.

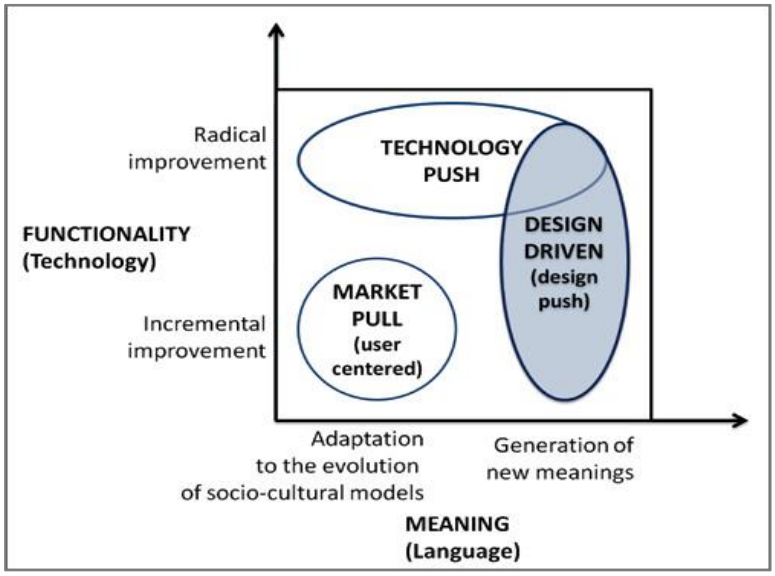


Figure 12 The three innovation strategies (Verganti, 2009a).[5]

Although design-driven innovation does take place, it is less prevalent in industry because R&D departments are populated by scientists and engineers, who generally view design as secondary to scientific development (Verganti, 2009a). Interestingly, Verganti (2009a) explains that design-driven innovation is rewarding, risky and complex, but is less expensive than breakthrough technology-push R&D.

R&D in the past was a key strategic asset for large corporations, which kept smaller competitors at bay due to the high capital cost required for investment in R&D resources (Chesbrough, 2003). However, a new paradigm opened up over time where newcomers with little R&D of their own were able to progress new ideas to market ahead of the large corporations (Chesbrough, 2003). In the past, the closed innovation model was all about ‘‘self-reliance: if you want something done right, you’ve got to do it yourself” (Chesbrough, 2003, p. 36) (Figure 13). The philosophy in the closed innovation model is that the company creates, develops and takes its own ideas to market, underpinned by its own large-scale R&D laboratories, as depicted by the funnel which filters research projects for market development. It was a hallmark of large 20th-century corporations, such as DuPont and IBM (Chesbrough, 2003).

In contrast, the approach of the newcomers is described as the open innovation model (Figure 13). In this model, a company can partner or acquire innovation from other external entities and still commercialise its own ideas (Chesbrough, 2003), thus giving it superior speed to market without the burden of having to expend on large R&D resources.

[5] Source: http://www.scielo.cl/scielo.php?pid=S0718-27242015000200003&script=sci_arttext

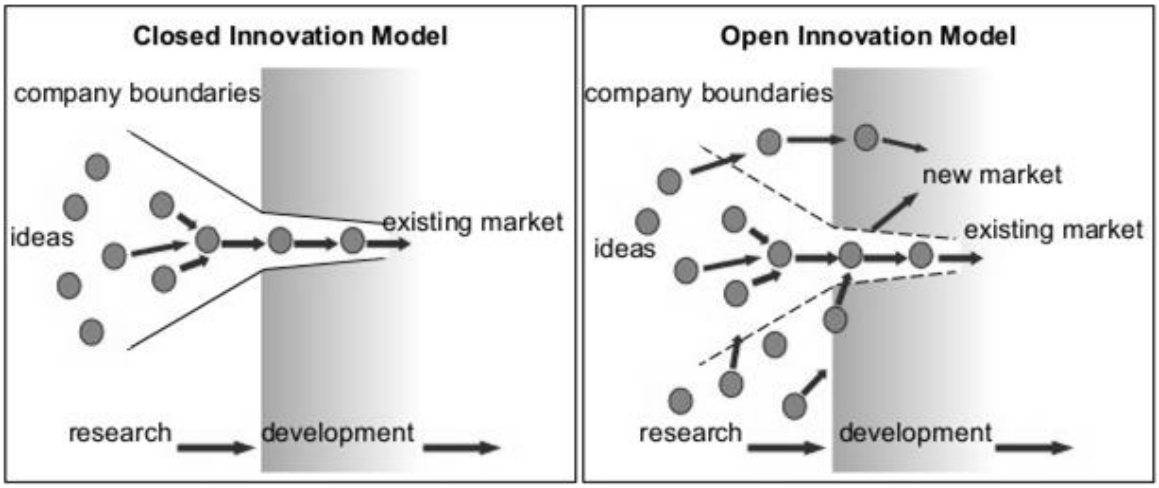


Figure 13 Closed innovation model and open innovation model (Chesbrough, 2003).[6]

The transition to open innovation became more visible towards the end of the 20th century. Chesbrough (2003) attributes a number of factors to this transition, such as the movement of knowledge workers between companies, universities being able to commercialise their own research, the rise of venture capital, intellectual property (IP) licencing, joint ventures (JVs) and entrepreneurial start-up companies. Nevertheless, Chesbrough (2003) argues that not all industries will migrate towards open innovation, such as the nuclear energy industry, which has little entrepreneurship or market interest.

Chesbrough (2003) postulates that a continuum exists along which different industries fit within two ends of the spectrum, with open innovation culture on one end and closed innovation culture on the other. The movie industry in Hollywood, where actors, producers, directors and crews form networks and alliances and partner up on ventures is considered an ideal example of open innovation culture (Chesbrough, 2003). Regardless, some companies persist with the old 20th-century closed innovation model irrespective of where the rest of their industry is heading, e.g. IBM (Chesbrough, 2003). Meanwhile, there has also been a rise in intermediaries who play the role of broker between industry participants for open innovation (Chesbrough, 2003).

"It's now conventional wisdom that virtually no company should innovate on its own" (Pisano & Verganti, 2008, p. 78). Different collaboration modes exist and the correct one to use depends on the strategic intent of the organisation in terms of building and capturing value. Pisano and Verganti (2008) propose that this comes down to asking two questions: (1) How open or closed do you want to be with your collaborators? (2) Who will decide on the collaborative activities? Based on these two questions, Pisano and Verganti (2008) define four ways to collaborate (Figure 14).

[6] Adapted from source: http://www.slideshare.net/wi2/cct-cm4-27201350

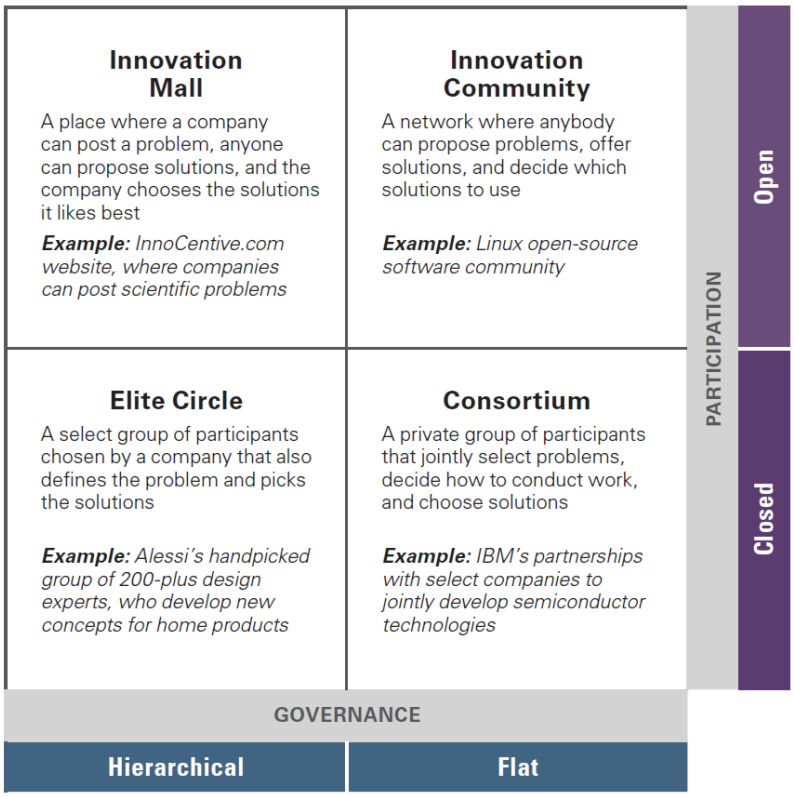


Figure 14 The four ways to collaborate (image source (Pisano & Verganti, 2008)).

For the four forms of collaboration shown in Figure 14, innovation mall, innovation community, elite circle and consortium, there are a range of associated advantages, challenges and enablers. This is summarised in Figure 15. For example, the open mode is not as effective at attracting the best collaborators or solutions, but can generate many participants and fresh ideas. By comparison, the closed mode can be inappropriate "if you don't know where to look for the solutions or who the key players are" (Pisano & Verganti, 2008, p. 80).

In terms of flat or hierarchical governance, it simply comes down to who gets to decide on the problems to tackle or the solution to adopt (Pisano & Verganti, 2008). Nonetheless, Verganti and Pisano (2008) point out that scholars sometimes incorrectly suggest that open mode collaboration is associated with flat governance and closed mode collaboration is somehow inferior, when it is not. This has implications for the ways in which universities collaborate with industry for research.

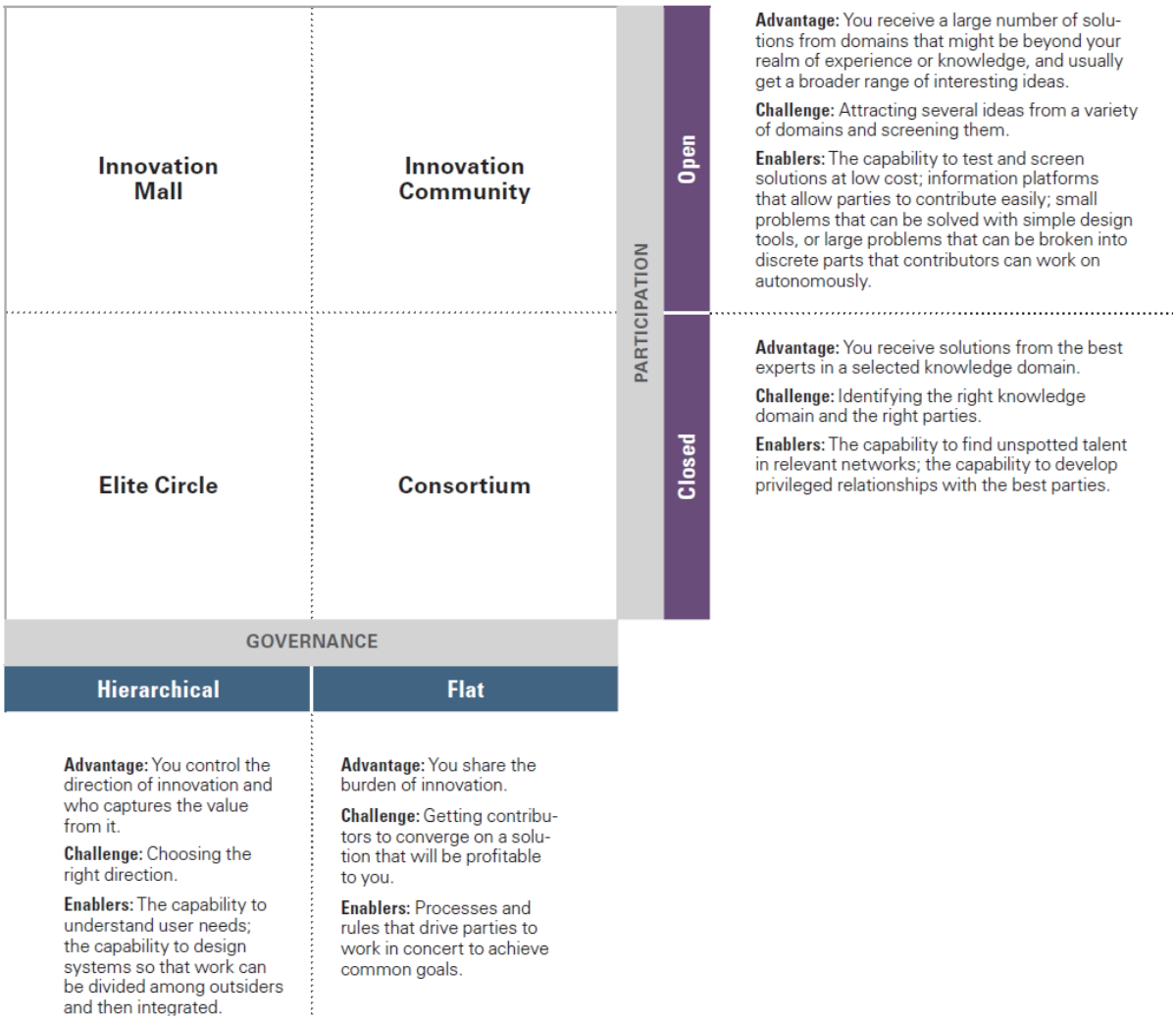


Figure 15 The four ways to collaborate with advantages, challenges and enablers (image source (Pisano & Verganti, 2008)).

However, in Chesbrough's view, "although university research is now more abundant and of higher quality than in the past, the flow of that knowledge into the commercial sector faces several obstacles" (2003, p. 41), such as the siloing effect in academic departments, which tends to discourage multidisciplinary collaboration. Furthermore, the ability for universities to commercialise their own research sometimes means that they make it too expensive for industry to access IP (Chesbrough, 2003). As a result, innovation imperatives can impact on collaboration success between industry and university, a dynamic that is relevant for IA centres in entrepreneurial universities.

According to a study done at MIT by Pertuzê et al. (2010) on 25 large multinational firms with intensive R&D operations in the USA, there are seven keys for collaboration success between industry and university:

1) Defining the project's strategic context in relation to the company research agenda.
2) Boundary-spanning project managers with technical, networking and product knowledge.
3) Sharing the vision of the collaboration with the university team.
4) Investing in long-term relationships.
5) Strengthening communication links with the university team.
6) Building positive awareness of the project within the company.
7) Providing internal support until the research can be exploited.

Pertuzê et al. (2010) go further to claim that "several factors widely thought to be important" (p. 86) do not affect collaboration between industry and university:

1) Presence of an executive champion.
2) Geographic proximity.
3) Overall project cost.
4) Types of research: basic, applied or advanced development.
5) Location of the project manager.

However, what is clear is that IA collaboration in ANZ is not aligned with the views presented by Pertuzê et al (2010). In fact, the literature on IA collaboration in ANZ suggests almost a completely opposing view to the further claims (1–5 above) (Lawrence & Bodger, 2006a; Lawrence & Bodger, 2006b; Lawrence, et al., 2015; Garrett-Jones & Turpin, 2007). Pertuzê et al (2010) present a view of their study being globally generalisable without specifically acknowledging its limitations. It is important to note that this study was US based, on IA collaboration between research-intensive large multinational firms and MIT. There are three significant drawbacks to this study that make it not applicable to ANZ: (1) 99% of firms in ANZ are SMEs and only 1% fit the description of large multinational firms (section 1.2); (2) most ANZ universities are striving to collaborate with industry (section 1.2), but in contrast firms are likely to flock to collaborate with MIT for its prestige, being the world's number one university (Quacquarelli Symonds World University Rankings, 2015a); and (3) ANZ does not have many large firms (1%), let alone large R&D-intensive multinational firms (section 1.2). These are important considerations for IA centres within ANZ universities.

Part B: Science & Technology Research Centres

2.5 S&T RESEARCH CENTRES

The first research centre is believed to have been established in 1816 in Connecticut, USA for agricultural experimentation, and over time such centres have influenced and changed university structure, especially since World War Two (Etzkowitz & Kemelgor, 1998). Modern forms of collaborative research centres did not emerge until the 1970s in the USA (Boardman & Bozeman, 2007). "A shift in gears is under way in which the funding of science is based increasingly on economic, health and social criteria" (Etzkowitz & Kemelgor, 1998, p. 288) and therefore a flexible form of research centre is required to accommodate such goals.

Centre disciplines can range from S&T, medicine and health to humanities and the arts, as well as business and law. However, for the purposes of this research and literature review the focus is limited to industry–academia collaborative S&T research centres, which are predominantly based on engineering and physical sciences.

2.5.1 WHAT IS A UNIVERSITY RESEARCH CENTRE?

According to Etzkowitz and Kemelgor (1998), a centre is not an ad hoc research group but a more formal scientific organisation which may eventually turn into a company. Centres are typically organised research units (ORUs) (Boardman & Bozeman, 2007). They enable a framework for the coordination and growth of a research theme, and act as a vehicle for organising internal university resources and attracting external funding (Etzkowitz & Kemelgor, 1998).

Sá (2008) states that some centres are simply networks of academics from different departments that share resources or infrastructure, e.g. a laboratory with specialised shared equipment. Some centres are multidisciplinary departments without the official department tag, and may evolve into departments (Sá, 2008). There is a differentiation in terms of level of organisation between a research centre, and research groups or networks, which are less formal (Youtie, et al., 2006).

In ANZ, research centres are described in a similar way, where centres are seen as delivering knowledge advancement to find solutions for global change with the use of multidisciplinary teams working in a dynamic research environment that spans institutional boundaries and fuses to create new ideas, technology, theory and application (University of South Australia, 2012).

2.5.2 RESEARCH CENTRE ORIGINS

In the entrepreneurial university, traditional academic interests and industry objectives are in a state of flux. There are continuous adjustment and negotiation (Styhre & Lind, 2010):

> A research centre is a joint venture between the university, industry and government organisations identifying some domain of research where industry and academy can benefit from collaborating. (Styhre & Lind, 2010, p. 910)

According to Styhre and Lind (2010), a research centre is expected to produce high-quality research output in the form of journal publications and articles, rather than executing development projects. In addition, a research centre is expected to strengthen the competitiveness of industry and contribute to the advancement of innovation, serving the needs of both industry and the academic community (Styhre & Lind, 2010).

Only a limited number of research studies have been conducted on the practices of entrepreneurial universities. Furthermore, this research has mainly been produced by public policy researchers and not by management scholars working on entrepreneurship or strategy (Styhre & Lind, 2010). Youtie, Libaers and Bozeman (2006) argue for positioning the concept of research centres as a policy tool in the form of an institution designed to drive advances in science and technology.

2.5.3 RESEARCH GROUPS TO RESEARCH CENTRES

It is important to consider the foundational roots that paved the way for research centres to evolve. Funding provided by government, which was once thought to endanger academic freedom, is the primary support for research within a university (Etzkowitz, 1992). Research projects in a university are typically headed by a lead academic and a team of academic colleagues and postgraduate students within a field of research or discipline, referred to as a research group. Etzkowitz (1992) states that the size of research groups varies and there has been a shift over the 20th century towards team-based research instead of individual research. In any one academic department of a university, there are collectives of such groups that contribute to research and teaching, consisting of professors, postdoctoral fellows, postgraduate students and technical staff (Etzkowitz, 1992). Research groups are said to operate through collegiality in the relative absence of hierarchical bureaucracy, which is deemed to be a hindrance for the production of research (Etzkowitz, 1992). Consequently, a research group may operate as a 'quasi-firm' according to Etzkowitz (1992), where it "has all the characteristics of a business firm except the profit motive" (p.33). Anyone that heads up these research groups, involving up to twenty researchers, in essence wears the hat of a 'research manager' who has to deal with obtaining support for researchers and managing equipment, budgets and project deadlines (Etzkowitz, 1992).

A number of research groups transition into becoming research centres. According to Etzkowitz (1992), the transition happens because there is a desire to acquire greater research funding and to reap the benefits of collaboration, which is sometimes multidisciplinary, to progress an area of research to scale. Nevertheless, while the number of university research centres has been increasing over time, many of these centres deviate very little from the traditional focus on academic research and publishing activities (Youtie, et al., 2006). This has been determined by Youtie et al. (2006) by conducting a cross-case analysis study of three research centres as case studies, which involved interviews and site visits. "Although centres proliferate, young scientists enter the academic world with the goal of establishing their own group" (Etzkowitz, 1992, p. 50).

In closing, the literature on research groups and research centres implies that very little has changed culturally in terms of approach, in the way academics engage with centres. It therefore poses a key challenge for IA centres to overcome traditional attitudes in shifting academic participant culture from a solo research-group mentality to a team-based IA centre approach.

According to Pfeffer and Sutton (2000), "productivity, performance, and innovation result from joint action, not just individual efforts and behaviour" (p. 197). This is not dissimilar to the context of centres, which require team work for success.

2.6 KEY DRIVERS FOR CENTRES

Centres are key mechanisms for the strategic generation of research outputs that address social and economic problems which are not easily addressed unilaterally by academic departments, government laboratories or industry in isolation (Boardman & Gray, 2010, p. 452). Coincidentally, it is impossible to accurately estimate numbers, but one study in 2010 indicate that there are over 37,000 research centres worldwide (Boardman & Gray, 2010).

2.6.1 RATIONALE FOR CENTRES IN UNIVERSITIES

Etzkowitz and Kemelgor (1998) argue that two drivers lead to the formation of centres: (1) competition in the discipline area; and (2) collaboration being a better strategy than going it alone for practical or theoretical problems from a multidisciplinary standpoint. Centres also foster the development of critical mass in specialised fields, creating prestige for universities and supporting the ongoing academic struggle for research funding (Etzkowitz & Kemelgor, 1998).

Centres are sometimes created to meet the external demands and needs of sponsors. Some of the government-funded centres involve multiple universities and public and/or private organisations (Sá, 2008).

"Through the establishment of a center, not only do academic scientists gain an organizational framework to access information and resources, but universities also increase the visibility of the campus research that place in multiple schools and departments" (Sá, 2008, p. 34). Over time, centres may develop a unique identity and become a significant source of funding, student and faculty talent, and prestige (Sá). However, centres are "temporary bodies that may close if funds run out" (Etzkowitz & Kemelgor, 1998, p. 277) and, according to Etzkowitz and Kemelgor, "centres have no rigid set of common characteristics" (p. 271).

2.6.2 POLICY IMPERATIVES

The agenda for research policy is becoming intertwined with innovation policy, especially with the increasing number of university–industry collaborative programs (Lundequist & Waxell, 2010).

Lundequist and Waxell (2010) state that there is no clear policy definition of what constitutes a centre. In fact, universities do not generally distinguish between centres and institutes, and these terms are used interchangeably (Stahler & Tash, 1994). It is possible to observe a variety of centres or institutes within universities, but it is not easy to define what these are (Sá, 2008).

According to the viewpoint of Lundequist and Waxell (2010), there have not been any serious attempts to systematically analyse the development of collaborative centres in the policy field, especially in relation to "how these challenge the more rigid academic structures of traditional and old university milieus, thus acting as an agent of change" (p. 264).

2.6.3 COLLABORATIVE CENTRES

Collaborative centres are versatile social and organisational alliances that can be structured in a variety of ways and can produce different results under different circumstances (Boardman & Gray, 2010). They are part of government innovation strategy in most developed countries (Boardman & Gray, 2010). However, goal synergy between collaborators is crucial and this can only be facilitated with appropriate organisation design, structure and coordination (Dooley & Kirk, 2007). Moreover, Philbin (2011) argues that there is a need for university centres to determine robust business cases in order to ensure sustainability for these collaborative centres. Although Philbin's study was in the UK, it reinforces the need for a recommended business model for IA centres in ANZ universities.

"A flexible form of organisation is required to be able to respond to change" (Dooley & Kirk, 2007, p. 327). In fact, Lundequist and Waxell (2010) state that the National Science Foundation (NSF) Engineering Research Centre (ERC) program has inspired collaborative centres globally, such as the Australian Cooperative Research Centres (CRC) program in 1990, the VINNOVA Competence Centres (now called VINN Excellence Centres) in Sweden in 1995 and the Kplus Competence Centres in Austria in 1998.

2.7 CENTRE DYNAMICS

Centre dynamics are important to the ways centres assimilate into the universities they are hosted within. The following sections provide an overview of centre dynamics with respect to host university arrangements, conflict management, provision for host university support, cost-sharing arrangements, rewards and recognition, and alignment between the host university and centre.

2.7.1 HOST UNIVERSITY ARRANGEMENTS

Host universities typically plan to attract external funding through the strategic creation of centres (Sá, 2008). Stahler and Tash (1994) suggest that the largest funded centres at the fastest growing universities complement the academic role of host departments by supporting interdepartmental

activity, as well as enhancing teaching and research within the host departments. Nevertheless, Stahler and Tash (1994) argue that the primary mission of centres is conducting research, and not teaching or external engagement. Furthermore, according to research conducted by Toof (2012), the engagement mission of a centre is challenged by a lack of clarity, limited support, reduced funding, traditional university culture, and overarching tension between research objectives and engagement objectives. Nonetheless, centres are used as role models for external engagement by the host university (Toof, 2012), even though they face scrutiny and are limited in resources for undertaking external engagement.

Moreover, centres enable bridging the activities in academia and the interests of society (Sá, 2008). They "provide academic scientists the means to pursue new relationships, source of ideas, funding opportunities, and audiences for their research outputs" (Sá, 2008, p. 39). However, there are general issues for all centres according to Arnold et al (2012), such as the treatment of overheads within the host university, funding for centre staff, functional governance and management processes, and access to facilities and equipment.

2.7.2 CONFLICT MANAGEMENT

Critics of centres state that they lack interdisciplinary collaboration, even though centres are about collaboration, and that centre affiliation can be disadvantageous for department careers and promotion because research is driven by funding agency interest, as opposed to academic research goals within departments (Stahler & Tash, 1994). Consequently, "antagonistic relations may develop among centers and departments" (Sá, 2008, p. 37) in regards to disputes over resources and control. In fact, conflicts between centres and departments are "not necessarily inevitable, they most likely occur when there is competition over such scarce resource as faculty time, internal funding support; space, equipment, and research infrastructure; and prestige" (Stahler & Tash, 1994, p. 543; Etzkowitz & Kemelgor, 1998).

Etzkowitz and Kemelgor (1998) exemplify this with professors having to choose between allocating a grant to a centre or to their department. The authors highlight the importance of university management in recognising the contributions of staff towards centres, especially since their career advancement is tied to their department. Stahler and Tash (1994) go further to state that these conflicts arise as a result of professional 'collegial envy' of those not involved in centres, e.g. privileges such as reduced teaching loads, greater resources and higher salaries add to the debate.

2.7.3 SUPPORT FOR A CENTRE

According to the literature, centres are generally reliant on external support, as well as support from the host university and host department within the host university, regardless of their level of success (Sá, 2008). Centres need internal support and guidance, and can enhance a research university's capability for funding with multidisciplinary collaboration, prestige and visibility (Stahler & Tash, 1994).

Indeed, reliance on external funding shapes the creation of centres and their continuation and, consequently, this is the market test for centres (Sá, 2008). However, centres can become independent of oversight without progressive monitoring and some scholars argue that a university should not initiate a centre if it is not prepared to resource it properly (Stahler & Tash, 1994).

Sometimes centres may develop their own inertia and continue to exist in the absence of serving any useful purpose. "The initiation or termination of centers is rarely guided by rational or systematic planning" (Stahler & Tash, 1994, p. 546). "Ever-increasing numbers of centers with varying levels of productivity and quality drain institutional resources over time and constrain the ability of the university to make further improvements" (Sá, 2008, p. 35). Scholars argue that it is difficult to terminate centres within a host university even when they lack external funding support or for

complex political reasons, e.g. when a centre is a researcher's 'pet project', or is used to retain a key academic or to avoid conflict (Sá, 2008).

2.7.4 COST-SHARING ARRANGEMENTS

There is agreement within universities that centres are excellent vehicles for focusing university resources to leverage external funding, but this should be done selectively, caution Stahler and Tash (1994), and in alignment with the host department or faculty. The difficulty is that host university "administrators often believe that centers can be 'cash cows' for the university, the reality is that centers require considerable investment in internal funds before they can be expected to generate significant external funding" (Stahler & Tash, 1994, p. 551). Even then, argue Stahler and Tash, centres will require internal support.

Undoubtedly, centres are seen as necessary for boosting a host university's research program and collaborations, provided that resources, centre leadership and university support are in place (Stahler & Tash, 1994). There may be an expectation by the host university that a centre can self-support through the collection of overheads from research grants for facilities and infrastructure (Sá, 2008).

2.7.5 REWARDS AND INCENTIVES

Traditional university reward systems are focused on "single-investigator discipline based research" (Sá, 2008, p. 37) and they are not set up to handle the growing emphasis on multidisciplinary collaboration, e.g. assignment of credit for the principal investigator in a research grant for a centre (Sá, 2008). Consequently, new university systems are being introduced to assign credit to centres and departments for collaboration on research grants as groups compete for recognition (Sá, 2008).

If both centres and departments are encouraged to win research grants but the reward systems fail to capture the collaboration effort, disincentives are created (Sá, 2008). Furthermore, part of the problem lies with university accounting procedures, where attribution of credit comes with political and cultural implications. Hence, clarity is needed in order to apportion credit between centres and departments. This can impact on junior staff in particular, on whether they engage with centres or not (Sá, 2008).

2.7.6 ALIGNMENT BETWEEN A CENTRE AND THE HOST UNIVERSITY

After starting a centre, it is essential to focus on its leadership to develop expectations (Stahler & Tash, 1994). As a starting point, the literature suggests that centres should devote considerable attention to their relationship with their host university, especially the host department (Stahler & Tash, 1994). Philbin (2011) describes in his case study of a successful industry–academia centre that, in addition to the centre collaboration, the industry partner had a strategic alliance with the host university. Therefore, it is evident that formal and informal approaches can be used to achieve alignment between a department and a centre (Sá, 2008).

It is advisable for centres to develop a strong identity to create new fields and discipline areas, rather than being buried in existing programs of the university (Youtie, et al., 2006). To go a step further, Boardman and Corey (2008) recommend that centres have strategic guidelines for academic development and open communications with the host department.

2.8 LEADERSHIP AND MANAGEMENT

The leadership structure and management culture of a centre need to reflect an entrepreneurial ideology that can bridge academic traditions and industry requirements. Academics tend to pursue long-term horizons, while industry wants to move on projects in real time (Styhre & Lind, 2010). However, industry partners of mature centres were more likely to appreciate a long-term view of developing research output (Styhre & Lind, 2010). It is up to the leaders and managers of centres to

bring the two cultures in industry and academia together for joint success within centres (Lawrence & Bodger, 2006b).

A study in the USA that looked at over twenty industry–university NSF-funded cooperative research centres grouped the success factors of these centres into five categories: (1) relationship with host university; (2) relationship with industry; (3) internal management; (4) research and technology strategy; and (5) individual attributes of the founders and managers (Geisler, et al., 1990). This robust study found that "the attributes of the individual founders and managers and their relations with the focal university are the best predictors of success in the early stages of the life of a center, whereas relations with industry and internal management are the best predictors of success of a center in the later stages" (Geisler, et al., 1990, p. 99). Therefore, leadership and management are the major factor for the success of a centre.

2.8.1 REPORTING LINES AND GOVERNANCE

In terms of reporting lines, there is a balancing act between autonomy (freedom to operate) and host-university control for a centre (Sá, 2008). Typically, "center directors may report to deans or to a provost or academic vice president, or to a university's research administrators, such as a vice provost or vice president for research" (Stahler & Tash, 1994, p. 545).

Stahler and Tash (1994) argue that the higher the reporting line, the more centres are considered a high priority within a university. To add to this, "an advisory committee with university and industry members helps to ensure industry relevance" (Etzkowitz & Kemelgor, 1998, p. 276). For example, a study that looked at Australian Cooperative Research Centres (CRCs) indicates that the majority of participants working in the CRCs felt the importance of representative governance, i.e. board representation, and that the centre's CEO and board were critical to its success (Garrett-Jones & Turpin, 2007).

2.8.2 LEADERSHIP STYLES AND MANAGEMENT APPROACHES

Philbin (2011) looked at the challenges and issues associated with organising academic work according to centre structures through a UK case study, with the assumption that institutes and centres are broadly equivalent. He found that challenges for centres included managing different reporting lines and the need for effective research coordination and collaboration across different participants.

Centres bear the imprint of the director's philosophy, vision, interest and goals (Stahler & Tash, 1994). However, to be successful, "center directors need scientific capability to command the respect of peers and the scientific community and to attract personnel to the unit. But they also need managerial and political skills to build alliances inside and outside the university, to aggregate resources, and use them effectively" (Sá, 2008, p. 34).

According to Stahler and Tash (1994), centres tend to have a more authoritarian management structure than departments. In fact, the more management knowledge and experience the centre director or manager has, the more structure and authority the centre will have (Boardman & Ponomariov, 2014).

In a study of 10 NSF centres looking at the different organisation structures of industry–university centres, it was found that there is a correlation between the complexity of the research performed and a centre's formal organisational structure, in terms of its vertical integration, levels of hierarchy, formalisation and centralised control (Hart, 2013).

Despite the importance of leadership and management needs for a centre, "scientists rarely have any formal training to fulfil managerial roles, center directors rely on practical experience to acquire these relevant skills" (Sá, 2008, p. 34). If leadership and management skills are "crucial to establishing a successful collaboration, there has to be a champion with a combination of personal dynamic

capabilities and who has established social relationships with individuals in senior positions in the companies and organisations which form the core of a strategic alliance" (Dooley & Kirk, 2007, p. 329). On that note, Philbin (2011) highlights the distinction between centre academic directors and administrative directors, with administrative directors taking the lead on managing processes related to centre operation while the academic director focuses on the research effort.

Given these complexities, "centre directors increasingly resemble a corporate chief executive officer (CEO)" (Etzkowitz & Kemelgor, 1998, p. 280). This is exemplified by how "an enthusiastic individual with a vision often brings colleagues together to develop a centre" (Etzkowitz & Kemelgor, 1998, p. 276). Ultimately, "the most successful centres combine an entrepreneurial director with a group of faculty who genuinely want to work together for the intellectual and practical reasons" (Etzkowitz & Kemelgor, 1998, p. 276).

2.8.3 MANAGEMENT CHALLENGES

Funding and long-term financial sustainability of a centre are concerns for centre directors and host university management alike, especially facing the challenges of limited budgets and competition for funding. Often philanthropy is looked on as a source of support for centres (Sá, 2008).

The success or failure of a centre at any stage of its life can be predicted by assessing a small set of factors, such as lack of motivation and entrepreneurial vigour of the centre's leaders, its reputation and financial stability, and retention of industrial members, as well as students and academics. This is in addition to the research achievements of the centre, and having long-term perspectives and clear objectives and a succession strategy for leadership, as well as the attributes of the founder and degree of university support as necessary preconditions (Geisler, et al., 1990).

Philbin (2011) states that, compared to the past when individual academics worked on their own science projects, complex science now increasingly demands collaboration. Hence, the relationships in collaboration can be as important as the research itself (Geisler, et al., 1990). There is also greater availability of funding for multidisciplinary research projects and centres (Philbin, 2011). As a result, challenges for centre management include collaboration development, financial program management, research project management, program reporting, governance, and risk and safety management (Philbin, 2011).

Garret-Jones and Turpin (2007) examined survey responses from 370 participants in the Australian CRC program to look at the experiences of participants and identify internal management issues, as well as external management with universities, government and industry sponsors. They conclude from their findings that bad experiences with CRCs were largely due to participant organisations not having specific management approaches to interface with CRCs. For example, some of the specific findings include frustration over the administrative burden on processes when working with CRCs, such as timesheets and onerous forms (Garrett-Jones & Turpin, 2007).

According to Dooley and Kirk (2007), trusted relationships and formal processes are required to overcome management challenges for centres. Also, when it comes to managing research activity of a centre and IP management issues, Dooley and Kirk have found that when "close relations have been established over a long period of time, there is a greater level of trust and openness between researchers relative to sharing research outputs" (p. 323).

2.8.4 STRATEGY AND CULTURE

Strategy and culture are two key aspects for a centre that are set by its leaders. Strategy refers to the vision, goals and objectives of a centre, while culture refers to its leadership and the cohesion that is created among key participants, including centre staff (Lawrence & Bodger, 2006a).

Philbin (2011) notes that strategy development for centres should be consistent with the strategy of the larger units, i.e. the host departments or faculties, within which a centre is located. Furthermore, strategic planning for a centre should have a structured approach (Philbin, 2011).

In terms of developing an actual strategy for an industry–academia collaborative centre, there are a number of broad categories to consider, namely: education, research and innovation, and industry interaction (Lawrence & Bodger, 2006a).

The cultural differences between industry and university also have a significant impact on collaborative centres (Lawrence & Bodger, 2006b). "Industry brings with it practical know how and professional business practice, while academia resonates the highest level of technical knowledge" (Lawrence & Bodger, 2006b, p. 2). It is therefore important for centres to develop cross-cultural management techniques. For example, on joint R&D projects in a centre, industry may value development over research, while academia may prefer research over development. Therefore, project managers need to understand this key difference to deliver on outcomes for both sides (Lawrence & Bodger, 2006b).

Overall, "one of the most satisfying elements of IA R&D is the opportunity to make a difference … together with the fulfilment of creating something based on an idea or concept" (Lawrence & Bodger, 2006b, p. 6), as a direct consequence of being able to combine the two cultures for joint success (Lawrence & Bodger, 2006b).

Culture overrides strategy, because by its very nature it determines the way strategy is derived and interpreted by human participants. The late Peter Drucker is famously said to have stated that "culture ate strategy for breakfast" (Hyken, 2015, p. para 1). It is also a factor that influences IA centres within universities, in terms of the adoption and implementation of strategy, i.e. how people will approach it.

2.9 RESOURCES

Resources for a centre are a key requirement in order to undertake activities. The following sections provide an overview of the literature that highlights factors relating to the human resourcing of centres, i.e. academic staff and centre staff. This includes conflicting demands on academic participants, role strain between working for a department and for a centre, incentives for academic participation, multidisciplinary collaboration and centre staffing.

2.9.1 CONFLICTING DEMANDS ON ACADEMIC PARTICIPANTS

As government research funding continues to shift towards multidisciplinary collaborative research centres and projects, academics end up facing conflicting demands between their academic role in a department and the demands of the multidisciplinary collaborative centre with which they are affiliated (Boardman & Ponomariov, 2014). Collaborative multidisciplinary centres place expectations on the behaviour of academic participants that do not align with the traditional reward system in a research university that recognises certain activities, such as individual peer-reviewed journal publication (Boardman & Ponomariov, 2014). Based on interviews conducted by Boardman and Ponomariov (2014) in the USA, reward systems were found to discourage participation in centres, especially for junior academics, when centres emphasised applied research or commercial activities with industry partners. However, according to Boardman and Ponomariov (2014), university management assumed that there was no problem in getting academics to engage with collaborative multidisciplinary centres.

Boardman and Ponomariov (2014), while focusing on the policy implications, suggest that this was due to junior academics wanting to get tenure at their university. Furthermore, Boardman and Bozeman (2007) found that role strain exists for academics who are affiliated with a centre while also having an academic appointment in a department. Hence, there are indeed conflicting demands

placed on the academic participants of centres (Boardman & Bozeman, 2007; Boardman & Ponomariov, 2014). Nevertheless, affiliation with government-sponsored centres correlates positively with the level of industry involvement, regardless of whether these centres have direct ties to industry or not (Boardman, 2009).

2.9.2 ROLE STRAIN BETWEEN ACADEMIC DEPARTMENT AND CENTRE

In another study comprising interviews with 21 academics associated with centres involving industry, which are more complex than traditional research centres, it was found that these centres bring traditional and conservative departments towards new ways of thinking about multidisciplinary work (Boardman & Bozeman, 2007). Nevertheless, there is an argument that academics will be less productive in teaching and research through involvement in centres (Boardman & Bozeman, 2007). Boardman and Bozeman (2007) found that many studies have given equal weight to non-research activities such as teaching but that, despite these studies, not much has changed in universities. They conclude that collaborative multidisciplinary centres are "central to the discourse on institutional complexity and academic science, with role strain constituting a side effect requiring clarification and remedy" (p. 437).

2.9.3 INCENTIVES FOR ACADEMIC PARTICIPATION IN CENTRES

Despite the presence of role strain issues, academics volunteer to work with industry-orientated multidisciplinary collaborative centres (Boardman & Bozeman, 2007). Boardman and Bozeman (2007) quote a centre director stating "people are driven by their own self-interests and if they recognize that what we want them to do is something they want to do, they will do it, it requires 'a big carrot and a little stick'" (p. 451). It is ultimately up to the individual academic to choose, with incentives such as access to students and the opportunity to connect with industry being present (Boardman & Bozeman, 2007).

When it comes to incentives and rewards, departments are "ill equipped to evaluate center research when making salary and promotion decisions, as the departments differ little today from those of the 1920s and are similar in disciplinary orientation, educational functions and reward systems" (Boardman & Bozeman, 2007, p. 450). A centre has few resources available to entice academic participation in the centre and many that who affiliate with a centre tend to avoid projects that do not align directly with reward systems in their home departments (Boardman & Bozeman, 2007).

Boardman and Bozeman (2007) found that: (1) cost-sharing agreements between departments and centres do not always reduce role strain; (2) bias in tenure and promotion criteria favours single disciplines over applied or commercial research; and (3) participation may be seen as time taken away from doing academic career advancing work (Boardman & Bozeman, 2007).

2.9.4 MULTIDISCIPLINARY COLLABORATION

As far as multidisciplinary capability for collaboration in a centre is concerned, the scientific and technical human capital of an individual academic's capability matters (Boardman, 2009). An analysis of academics' *curricula vitae* and questionnaires by Lin and Bozeman (2006) shows that researchers with industry experience supported more students and those with industry–university research centre affiliation or past industry experience had advantages over those with no industry participation. For example, the academics with industry affiliation were found to have more research network connectivity with industry and other universities and their annual publication output was higher than for those without industry centre affiliation or experience (Lin & Bozeman, 2006). These are key academic performance indicators in a university.

Furthermore, the results of Corley's (2005) US study suggest that multidisciplinary centres might actually serve as a mechanism for gender balance and improving overall productivity levels of both male and female academics. This conclusion is based on findings pertaining to the publication output statistics of centre-affiliated academics in science and engineering (Corley, 2005).

Based on another study by Styhre and Lind (2010) using case studies, interviews and participative observations of 10 centres, it has been found that perceptions of research centres by academics include opportunities for new collaborations with industry, thus suggesting an inevitable shift in academia towards complex collaborations and an emphasis on applied research (Styhre & Lind, 2010). Many academics also highlighted the need for professional management capability and the importance of internal relationships and strong centre leadership for the handling of collaborative projects (Styhre & Lind, 2010).

Dooley and Kirk (2007), using a single case study of a pharmaceutical industry–university centre in the UK, highlight time as a key factor in demands to collaborate with industry. This is further exemplified by a paper by Garrett-Jones and Turpin (2007) on Australian CRCs, where they indicate that "the way the CRCs were structured made it difficult for partners to assess whether each other was 'pulling their weight': costing models between partners are wildly different and project budgeting is a major source of mistrust" (p. 18).

Another concern that has been studied by some scholars is the influence of research centres on individual academics and their research collaborations. Boardman and Corley (2008) compared research conducted by individual academics to collaborating within the home university, collaborating with researchers in other universities and collaborating with industry, government laboratories and international researchers. By using secondary survey data collected by another group, Boardman and Corley (2008) found that 32% of the academics surveyed were affiliated with a research centre and that centre affiliation actually increased university–industry research collaboration at the individual level.

2.9.5 CENTRE STAFF AND ENTREPRENEURIAL PROFESSORS

"The continuing dilemma of centres is to maintain a balance between intellectual focus and resources" (Etzkowitz & Kemelgor, 1998, p. 283). This means that some centres ultimately end up requiring their own dedicated staff in addition to academic participants from departments. In fact, centres can accumulate research staff who pursue their careers entirely within the centre, despite the lack of tenure (Etzkowitz & Kemelgor, 1998), i.e. fixed-term contracts. According to Etzkowitz and Kemelgor (2012), centre staff appreciate the full freedom of being able to work on research without the usual pressures of being an academic, but they can still submit grant proposals and supervise students. However, they may have less status and privileges than their academic colleagues in the department (Etzkowitz & Kemelgor, 1998). This means centre staff are caught between being recognised as academic staff versus general staff in a university (section 1.2.4).

Going back to the entrepreneurial university theory, the concept of an entrepreneurial professor has emerged as being someone who can mediate between discovery research and applied research that is aligned with external objectives (Styhre & Lind, 2010). The concepts of the entrepreneurial university and the entrepreneurial professor are therefore both images of a future university that is in the making (Styhre & Lind, 2010).

Styhre and Lind (2010) highlight the significant challenges when an academic without training or experience with industry is required to act as an entrepreneurial professor. Similarly, industry participants without collaboration experience with academia could also find it difficult and equally frustrating (Styhre & Lind, 2010).

The resource-related issues identified in the literature highlight the importance of the complexities associated with the operation of centres. Therefore, it is crucial for a recommended business model for IA centres to accommodate such issues.

2.10 CENTRE OPERATIONS

Multidisciplinary collaborative research centres, often involving industry, are organised around research themes and do conduct not only research but also teaching and external activity (e.g. client services, industry liaison and technology transfer). These centres also have research collaborations with other universities and industry partners (Youtie, et al., 2006). According to Youtie et al. (2006), the NSF ERC program in the USA exemplifies the multipurpose multidisciplinary university research centre (MMURC). MMURCs are key for government and industry to achieve social and economic outcomes through science and technology (Boardman & Gray, 2010).

Dooley and Kirk (2007) argue that IA collaboration, underpinned by industry and government funding, leads to new capabilities in the university. They also stipulate that publications are not hampered by the needs of industry collaborators. Although there are clear benefits, there are also challenges due to cultural differences between industry and academia on issues such as timescales, setting clear objectives, pressure to publish, confidentiality and IP ownership (Dooley & Kirk, 2007).

However, some academics view the focus on large-scale, high-profile centres as a hindrance to the development and emergence of new innovations achieved through small projects (Styhre & Lind, 2010). Moreover, evaluating the impact from centres has been found to be difficult: (1) patents are too far downstream; (2) publications from applied research work are less likely; and (3) the economic impact is difficult to measure in the short-term (Styhre & Lind, 2010). Nevertheless, Styhre and Lind (2010) argue that "the best way to address the value of the centre was to let external researchers review the research centre work in its entirety" (p. 919), i.e. by taking a broad, holistic, bird's-eye view.

Aligning the needs of government and industry can help obtain funding but can also bring forth challenges, according to Philbin (2011), such as to ensure the work carried out is of a high enough standard for academic publication. Moreover, the medium to longer term viability of a centre is contingent on its positioning into a specific research domain with respect to government and industry sponsor interests, and to deliver on research and teaching within a framework (Philbin, 2011). Hence, "an adequate focus on financial sustainability for such initiatives is sensible" (Philbin, 2011, p. 106).

In terms of incentives for industry, it is perceived that "the lower cost of R&D expenditure of university research laboratories as opposed to their industrial counterparts … is attractive" (Dooley & Kirk, 2007, p. 320). Dooley and Kirk (2007) also state that a university engages with industry in order to benefit from increased research funding and to access proprietary technology from industry. However, this view of Dooley and Kirk seems counterintuitive. Industry is seeking engagement with universities to develop new knowledge in order to commercialise it. It seems irrational for universities to seek proprietary technology from industry and to assume that industry would be willing to share that.

The following section provides an overview of the literature relating to centre operations, including the sustainability of funding for a centre and centre activities.

2.10.1 THE SUSTAINABILITY OF FUNDING

When considering financial sustainability for research centres, one major problem occurs when "centres come 'off-programme'" (Arnold, et al., 2012, p. 47) and require funding so as to remain sustainable beyond the initial funding period (Philbin, 2011). In their study of Irish research centres, Arnold et al. (2012) estimate that a centre requires 20–30% of core funding to maintain key activities such as governance, management and a small amount of research. Furthermore, Arnold et al. (2012) state that a few smaller centres in Ireland have been able to utilise industry membership fees, contract research and grants to enable them to be financially sustainable once core government funding ceased.

Philbin (2011), in his case study of a research centre in the UK, refers to the importance of financial leverage, which can help an industry sponsor continue to justify their investment in a centre. "Another major area of risk to the Institute is the long-term sustainability of its funding base, especially sustainability beyond the initial … funding term" (Philbin, 2011, p. 114). To offset the major risk of unsustainable funding beyond an initial term, e.g. 5 years, Philbin (2011) suggests that a centre should be looking to market its research and training capabilities to many industry partners beyond the initial funding term of the centre, even if the centre is exclusive to a single industry partner over the initial term, in addition to submitting proposals to government for funding. However, "it is important to recognise that not all centres need to, nor can, survive indefinitely in their current format once core funding comes to an end" (Arnold, et al., 2012, p. 62). This is a key point. It is important to consider that government funding program time limits have no relationship to the focus area of a centre nor the industry it serves. Therefore, it is illogical to assume that a centre has become irrelevant when core government program funding ceases. Hence, business models for centres need to transcend government core-funding time limits and aim to be self-sustaining.

Furthermore, based on a study of 335 companies involved with 18 NSF ERCs, Feller, Ailes and Roessner (2002) found that for these centres having strategically planned research, infrastructure, and postgraduate and undergraduate education in multidisciplinary industry-based projects "evidently removes a major lever that private firms use to justify support for generic, pre-competitive research" (p. 473). Their findings also indicate that industry engaged in these centres for "upstream modes of knowledge rather than specific products and processes" (Feller, et al., 2002, p. 457). Nonetheless, there is also a looming problem with continuation of industry support in the USA for NSF ERCs when NSF funding terminates after an 11-year term (Feller, et al., 2002).

However, some centres have managed to be self-sustainable without government seed funding, through the use of an industry membership model, while providing appropriate research status for its centre staff to undertake multidisciplinary, collaborative R&D and in parallel produce academic outputs such as publications (Lawrence & Bodger, 2005).

2.10.2 CENTRE ACTIVITIES

"Findings point to strong interest and support by firms of the knowledge-generating, research, and education roles of universities, especially when accompanied by a long-term, strategically planned research program" (Feller, et al., 2002, p. 473). This is reinforced by Etzkowitz and Kemelgor (1998), that some of the motives found for the formation of centres include the creation of high-quality graduates, pre-competitive research, collaboration with industry researchers, testing the industry relevance of research and universities seeing industry as the final customer for students and research.

It is important to ensure that collaboration with industry does not damage the reputation of the centre in the eyes of the government funding agency (Dooley & Kirk, 2007). Universities have been urged to "ensure presence of high profile academics" (p. 330), thereby ensuring that the collaborative area for research is underpinned by core competency, and that processes are put in place for knowledge exchange and technology transfer (Dooley & Kirk, 2007). Indeed, "there is little need for a formal technology-transfer office when company and university researchers can interact freely at a centre" (Etzkowitz & Kemelgor, 1998, p. 284).

Dooley and Kirk (2007) argue that the presence of enabling capabilities such as auxiliary services to support collaboration (e.g. testing services) is viewed as value-adding to the company, rather than an additional revenue stream for the centre: "Ancillary services can deepen relationships within the consortium and increase the benefit of all members" (p. 330). In terms of the specific issues that face long-term industry–academia centres, diversification is a sensible approach (Arnold, et al., 2012). However, diversification of activities can weaken centres if they do not have defined research programs and skilled management teams (Arnold, et al., 2012). Diversification can make activities

become fragmented into short-term projects, especially if they become industry orientated, requiring considerable management (Arnold, et al., 2012). Nevertheless, “some centres incorporate product development projects such as are usually carried out in industry. Some establish new courses and even degree courses” (Etzkowitz & Kemelgor, 1998, p. 280).

Dooley and Kirk (2007) indicate that the key challenge for universities is how to keep the emphasis on long-term research instead of short-term contract research. It is perceived that when an industry partner wants a project done through a centre, “these projects are like concrete assignments and do not result in any publications. Such assignments are considered as exciting although time to perform them is a limiting factor” (Lind, et al., 2013, p. 80). “A key concern is how to increase the involvement of industry, to put the problems of the industry into a research context” (Lind, et al., 2013, p. 81). ERCs have also been found to have pressure on their research portfolios to undertake applied research and short-term contracts (Feller, et al., 2002).

In fact, collaborative efforts in industry–university centres are always in a state of flux because, between practical and theoretical research interests, “there is a need to understand such collaborative work on the basis of analytical models that is affirmative towards this dualism” (Styhre & Lind, 2010, p. 922). However, the effect of industry involvement in a centre’s research can be subtle. Researchers may pursue their own research goals by shaping them to fit an industry partner’s interest (Etzkowitz & Kemelgor, 1998).

“Setting the right scope and direction in the research agenda and finding the appropriate mix of industrial partners are important in order to achieve and maintain open and developed collaboration” (Lind, et al., 2013, p. 83). Philbin (2011) suggests the need for balance between the applied research and consulting projects that an industry partner wants, and research that is publishable. A strategy that Philbin (2011) supports is to have principal investigators setting the research agenda so that projects can be aligned to publication. Even so, Etzkowitz and Kemelgor (1998) warn that some centres exist as a facade for an individual’s research program, while others are there to service a need for shared equipment; moreover, “Some researchers resist changing their research goals even when receiving economic development funds” (p. 28).

In terms of the collaboration and networking aspects of multidisciplinary collaborative centres, many researchers find value in the aspect of networking with other researchers and end-users in industry (Garrett-Jones & Turpin, 2007).

Furthermore, to build an international agenda or profile for a centre, Philbin (2011) suggests that centres should participate in international conferences and publish in leading journals, in addition to hosting international conferences, symposiums and research meetings where leading practitioners are invited from around the world. However, there is some caution that international approaches should only be attempted in order to achieve scientific objectives rather than profile per se, because it is hard to sustain international activity (Philbin, 2011).

Overall, the operational issues for centres highlighted in the literature advocate the need for the adoption of professional management practices and processes, which can bring both industry and university participants to work cohesively together (Lawrence & Bodger, 2006b). It alludes to the need for all IA centres to have a dedicated operations manager, in addition to full-time or part-time centre directors, in order to manage such complexities.

2.11 THEORETICAL CONCEPTS FOR CENTRE CATEGORISATION

There is currently no reference to business models in the literature for S&T IA collaborative centres within ANZ universities or overseas universities. However, the literature does contain scattered classifications for collaborative centres that are not exclusive to IA collaboration. Nevertheless, none of these classifications in the existing body of knowledge specifically extend towards combining a

definitive typology with an economic model for KE impact in the entrepreneurial university, i.e. a recommended business model for S&T IA centres within entrepreneurial universities.

Furthermore, there is no classification management toolkit in existence for the cross-comparison and rapid assessment of research centres in universities. Such a toolkit would aid in the planning and development of fit-for-purpose business models and strategy for centres in universities.

The next section outlines existing classifications for collaborative centres found in the literature. The existing diverse classifications are listed in the block diagram shown in Figure 16. The list of classifications indicates approaches that vary between structural and functional perspectives. However, there does not appear to be a single classification approach that integrates both the structure and function of a centre, nor is there a classification that considers the financial perspective or the activity-based output perspective of a centre in terms of value creation for the KE. This seems to indicate a gap in the existing knowledge base pertaining to collaborative centre classification, further necessitating the building of a recommended business model that considers the more complex reality of S&T IA centres within ANZ universities. Such a tool would allow for the cross-comparison of research centres within universities.

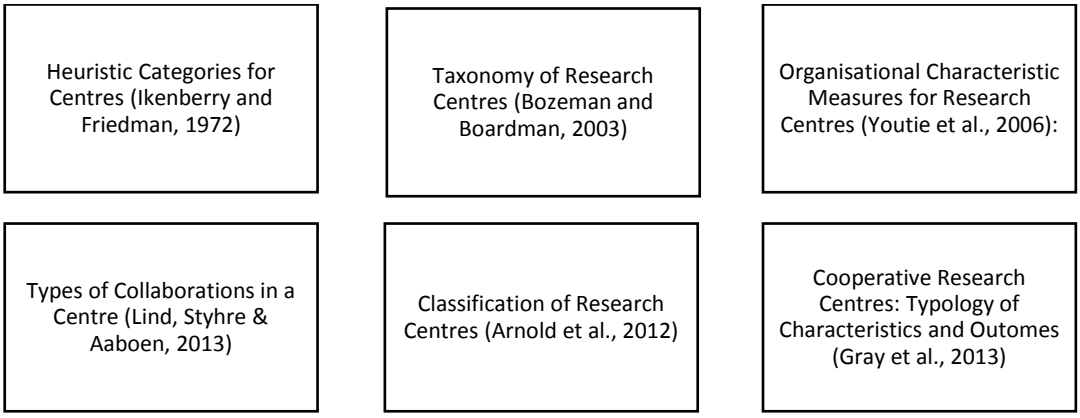


Figure 16 Summary of existing typologies for collaborative centres in the current literature.

2.11.1 HEURISTIC CATEGORIES FOR CENTRES

One of the earliest attempts in the literature to categorise centres within universities is that of Ikenberry and Friedman in 1972 (Hall, 2011). They propose that centres have three distinct types: standard, adaptive and shadow, as shown in Table 1.

These "center type categories provide a frame in which to place different types of centers to serve different functions within a university system" (Hall, 2011, p. 26).

"After 40 years, Ikenberry and Friedman's heuristic categories are still valuable as a way to categorize center types" (Hall, 2011, p. 26) and are particularly useful for categorising centres in terms of finance, human resources and physical infrastructure (Hall, 2011). However, the standard type and the adaptive type appear to resemble IA collaborative centres as described previously (section 2.5).

Table 1 Heuristic categories for centres (Ikenberry & Friedman, 1972, as cited by Hall, 2011).

Standard Type:
A standard type centre has stability in goals and resources to house, equip and support employment of administrative or professional staff, academics and students. These centres have the ability to draw on financial resources from a variety of sources including government (Hall, 2011). Furthermore, a standard type centre has status similar to a department within a university. It may have a space allocation in a department or even its own building, with an advisory board and bespoke policies and procedures (Hall, 2011).
Adaptive Type:
An adaptive type centre undergoes continuous redefining of goals, circulation of projects and flexible approaches to staff resources to suit an adaptive approach to instability in funding (Hall, 2011). An adaptive centre typically does not own resources but merely uses the resources from the host university, e.g. academic staff and equipment, on a needs basis to suit the requirements of a project or service request (Hall, 2011). Moreover, they can appear deceptively bigger and more well resourced than they actually are on their website (Hall, 2011).
Shadow Type:
The shadow type has no staff, budget, resources, space or visible achievements (Hall, 2011). They are sometimes called a 'paper centre' or 'paper institutes' and usually exist as a forum for teams of academics or for an individual academic's personal ambitions, facade to the world or ego (Hall, 2011).

2.11.2 TAXONOMY OF RESEARCH CENTRES

The taxonomy of research centres developed by Bozeman and Boardman in 2003 is a way of distinguishing different types of research centres from an academic department (Toof, 2012) (Table 2). It describes the types of research centres, in comparison to academic departments, followed by their levels of internal and external engagement, non-research activities and types of research on which they focus. The 'complex research centre' and the 'multipurpose, multidiscipline research centre' types broadly embody IA collaborative centres as presented earlier (section 2.5).

Table 2 Taxonomy of research centres (adapted from Bozeman & Boardman 2003 as cited by Toof (2012)).

Research Unit Type	**Horizontal Relations**	**External Relations**	**Extra-Research Activities**	**Research Problem Focus**
Academic Department	Minimal, except for those pertaining to curriculum administration	Simple and decentralised	Teaching, university and professional service	Discipline-based, provides consensus for rewards system
Simple Research Centre	Simple, sometimes no significant ones other than to department	Simple, negotiated by researchers interacting with networks of other academic researchers and government funding agencies	Few or none	Based on narrow set of problems, usually established by discipline-based 'normal science'
Complex Research Centre	Simple, sometimes no significant ones other than to department	Moderate complexity, including not only academic networks but other knowledge-user types, especially industry	More extensive including an expanded educational role or industrial outreach or brokering diverse network members	Mix of problem-driven topics and topics set by discipline or field specialisation demands

Complex Research Centre	Varies, usually very complex, cutting across many units	Complex, often including multiple external industry, government and university sectors	Multiple, often including educational role, industrial interaction, scientific and professional brokering, community outreach	Almost entirely problem-driven, not tracking closely to disciplines and established scientific and technical specialisations

2.11.3 ORGANISATIONAL CHARACTERISTIC MEASURES FOR RESEARCH CENTRES

The concept of the multipurpose multidisciplinary university research centre (MMURC), initially introduced by Bozeman and Boardman in 2003, is considered the principal vehicle for the entrepreneurial university (Styhre & Lind, 2010; Youtie, et al., 2006). Although it is less common, it is more demanding on leadership and management skills, given the complexities of collaboration. Hence, the more conventional 'university research centre' (URC) is rather more widespread (Styhre & Lind, 2010; Youtie, et al., 2006).

Youtie et al. (2006) argue that MMURCs have been created because of limitations in departments to be able to cross discipline boundaries, have clear research agendas, and engage with multiple funding agencies or companies and other external organisations. These types of centres have "received the most attention from policy-makers, as well as billions of dollars of research funding" (p. 1057).

Youtie et al. (2006) present a theoretical framework that suggests a parallel development over time of two streams: (1) institutionalisation of a centre; and (2) development of knowledge through the centre. In this framework, important research transcends over time to become a fully articulated research centre, while an interesting topic of research transforms into a reputable scientific discipline (Youtie, et al., 2006). Furthermore, Youtie et al. provide a set of organisational measures for research centres which go from minimal characteristics to fully articulated characteristics and, finally, a set of accompanying characteristics (Table 3): "It provides an organizing framework for considering the level of articulation of research centers, and ultimately the impact" (p. 1059).

Table 3 The organisational characteristic measures for research centres (Youtie, et al., 2006).

Minimal characteristics of research centres	**Fully articulated research centres**	**Accompanying characteristics**
Provision of external resources	Hierarchy	Grants and contracts; multiple resources
Agreements about resource sharing and access conditions	Administrative apparatus	Centre-salaried personnel; formal personnel policies and guidelines
Internal recognition of centre's institutional status	Apparatus for authoritative allocation of common pool resources, beyond initial agreement	Inter-organisational ties; multiple professional and organisational roles
Shared space (including virtual space)	External (beyond research specialists) recognition of a centre's status; finite beginning and ending points; formal founding mechanism; authoritative plans/objectives; one or more generally recognised entry portals for external actors	Multiple categories of research outputs; students, educational function; multiple fields and disciplines; diverse stakeholders/performance standards; process for setting research agenda

Using the framework above, Youtie et al. (2006) conducted a cross-case analysis of three centres using site visits and interviews, in addition to two further mini-cases with phone interviews. They found that none truly conformed to the complete features articulated in Table 3. They also noted that the formalisation of a centre and, to a lesser degree, the degree of institutionalisation of a centre correlate with the age of the centre, i.e. the older the centre, the more institutionalised and formalised it is. Nevertheless, according to these scholars, centres can be successful without having

all the features described in Table 3. However, they urge that "it is vital for a centre building program to have a fully articulated degree of institutionalization" (p. 106) as a means to accelerate collaborative linkages and research output. Moreover, the combined sub-categories of organisational characteristic measures in Table 3 appear to support the elements of collaborative centres described beforehand (section 2.5).

2.11.4 TYPES OF COLLABORATIONS IN A CENTRE

From a qualitative research study of three centres in a Swedish technical university by Lind et al. (2013), the four forms of collaboration in a centre are stated to be (Figure 17):

1) Distanced – relationship between industry and academia is weak, academics undertake research funded by industry.
2) Translational – research happens in both directions in parallel for papers and products as outputs; there is communication and interdependence between both sides.
3) Specified – opposite of distanced, where industry specifies what the research ought to be.
4) Developed – industry, university and funding agency (e.g. government) are all involved in setting the research agenda, but otherwise the same as translational.

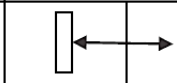
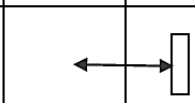
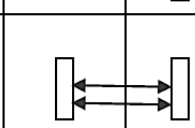
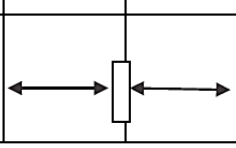
Collaboration form	Dominant actor	Process	Illustration Industry University
Specified form of collaboration	Industry	Research process towards product.	
Distanced form of collaboration	University	Research process towards research results.	
Translational form of collaboration	Industry and University	Two research processes in parallel towards product and research results.	
Developed form of collaboration	Industry and University	Research process towards product and research results.	

Figure 17 The four forms of collaboration in a research centre (Lind, et al., 2013).

Lind et al. (2013) suggest that the translational form and developed form are the best forms of research collaboration between a university and industry via a centre. This view aligns with the overarching essence of collaborative centres described previously (section 2.5), but it is not something that can drive strategy. It is an observational classification. In fact, "few studies have focused on the collaborations per se in research centres, taking the different institutional logics of the actors involved in the collaboration into account" (Lind, et al., 2013, p. 70).

2.11.5 CLASSIFICATION OF RESEARCH CENTRES

Even though there is no definitive description for a research centre per se, according to Arnold et al. (2012) a range of research centres can be classified across a spectrum, ranging from those that undertake basic research through to those that focus on applied research. This includes research centres based in universities, standalone publicly funded research institutes and government laboratories (Arnold, et al., 2012).

Arnold et al. (2012) have developed a classification to align with Pasteur's Quadrant, which is a well-known concept for segmenting the various forms of research (Figure 18). Pasteur's Quadrant maps research types from 'pure basic research' to 'use-inspired basic research' and 'pure applied research'

with respect to the directive for the research in terms of 'consideration of use' and 'quest for fundamental understanding'. The scientist's name listed in brackets is an exemplar for using the type of research within that segment.

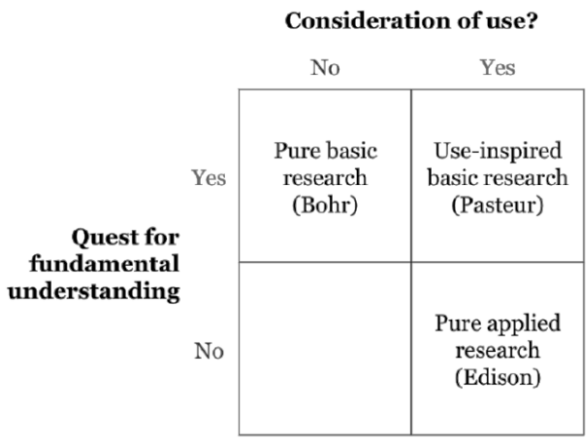


Figure 18 Pasteur's Quadrant (Arnold, et al., 2012).

The characterisation by Arnold et al. (2012) is shown in Figure 19. The research centre classification type that is of interest for this literature review is the industry–academia collaborative competence centres/industry-facing centres based within universities, i.e. higher education institutes (HEIs), described as:

> Interdisciplinary and generally problem-focused in the research they do, demanding 'horizontal' networking across traditional HEI structures. Their long-term presence on campus and their engagement with postgraduate education draws them into closer contact and cooperation with HEIs' 'core business' of education and research than is often the case with other linkage actions, which tend to focus more purely on research. By drawing industry personnel onto campus to join in research, they also extend academics' networks into the industrial research community. It is central to the idea of competence centres that they aim to do more fundamental types of research than is normally possible in industry, or even in conventional academic/industrial collaboration. (Arnold, et al., 2012, p. 70)

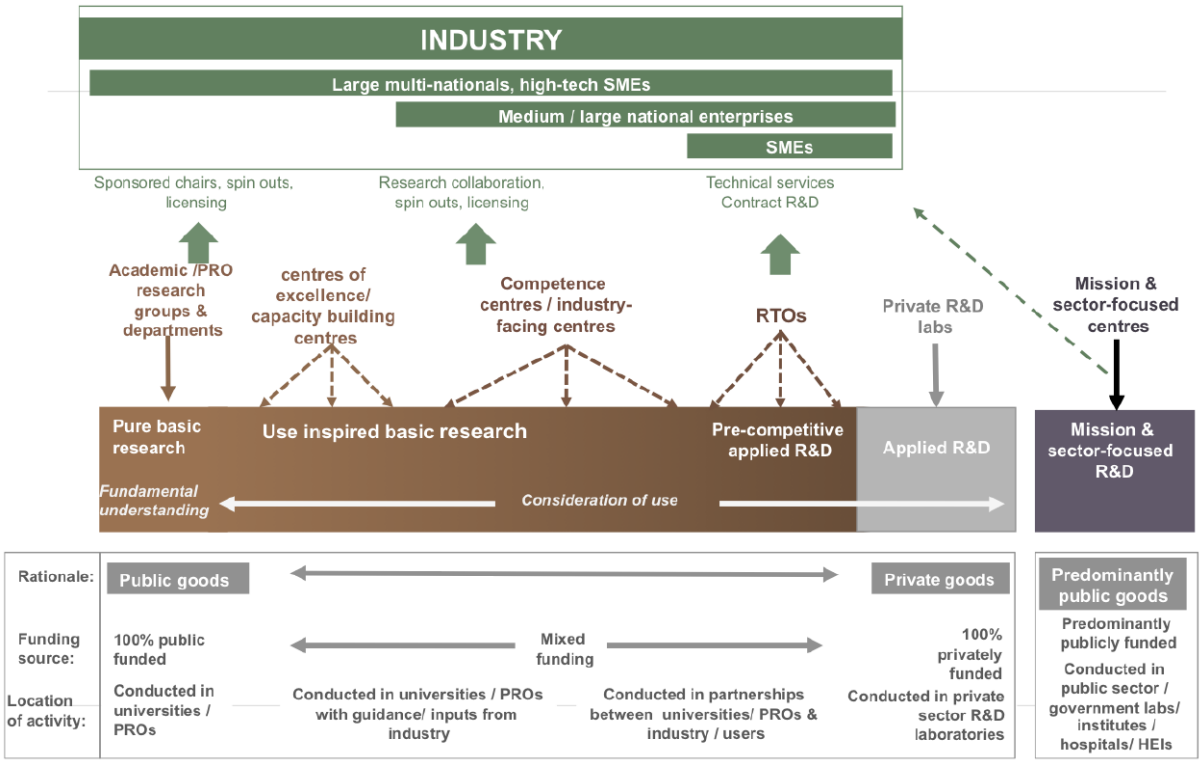


Figure 19 Depiction of industry engagement across the research spectrum (image source (Arnold, et al., 2012)).

On the left-hand side of the spectrum (Figure 19) is basic research, which is deemed to be a public good and usually conducted in universities (Arnold, et al., 2012); on the right-hand side is applied R&D, which is deemed to be for industry good and predominantly conducted within company labs and R&D subcontracting firms (Arnold, et al., 2012), which may include universities. Accordingly, there is a range of research entities that couple directly with the types of research required, i.e. pure basic research, use-inspired basic research, pre-competitive R&D, applied R&D, and mission and sector focused R&D, as shown in the spectrum of Figure 19.

In terms of actual research entities (Figure 19), this can range across academic departments, centres of excellence, competence centres/industry-facing centres, research technology organisations (RTOs), private R&D labs and mission-focused centres. Arnold et al. (2012) note that industry funding increases from left to right with the exception of mission-focused centres, which are mainly government funded. They go further to show the types of industry that are likely to interact with the various research entities along the spectrum. This includes the large multinationals and high-tech SMEs through to medium and large national companies, and SMEs. These scholars present the view that the larger technology and engineering companies will engage with a centre on the use-inspired basic research section of the spectrum, while pharmaceutical and materials companies will gravitate towards the left on basic research and SMEs will concentrate on the right with applied R&D (Arnold, et al., 2012).

The competence centres/industry-facing centres (Figure 19) are the S&T IA centres that fall within the scope of this thesis for the recommended ANZ business model.

2.11.6 COOPERATIVE RESEARCH CENTRES

Grey, Boardman and Rivers (2013) attempt to provide a general definition for the broadly used term 'cooperative research centre' (CRC),[7] which in their view is consistent with the notion of: (1) research collectivisation; (2) a cooperative mandate in research policy; and (3) advances in open innovation.

[7] Not be confused with Australian cooperative research centres (CRCs), which are independent of universities.

They refer to these combined concepts as social and organisational forces (Gray, et al., 2013) and define CRCs as:

> an organization or unit within a larger organization that performs research and also has an explicit mission (and related activities) to promote, directly or indirectly, cross-sector collaboration, knowledge and technology transfer, and ultimately innovation. (Gray, et al., 2013, p. 9)

Taking this definition a step further, Gray et al. (2013) stipulate that a CRC must have a formal organisational structure, be research active and undertake cross-sector collaboration between university, industry and/or government for technology and knowledge transfer. The combination of these three elements is considered to be the defining characteristic of a CRC (Figure 20).

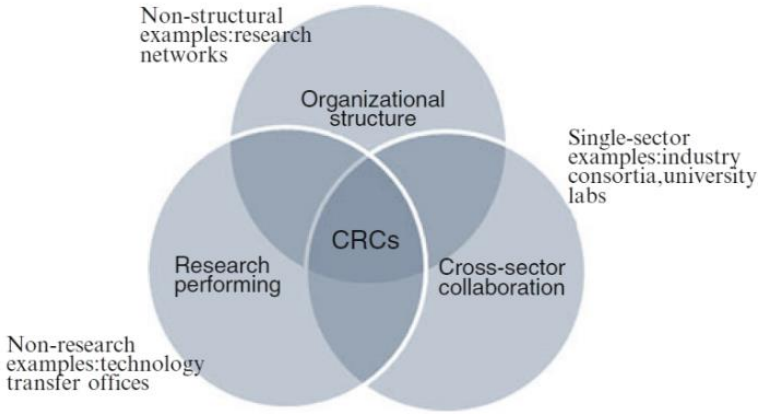


Figure 20 Definitive characteristics of a CRC (image source (Gray, et al., 2013)).

Building on the definition described in Figure 20, the CRC concept encompasses versatility due to the variety of forms that a centre defined as a CRC can take within the three-circle Venn diagram (Gray, et al., 2013). This means that "CRCs can and have been used to achieve knowledge creation, technology transfer, commercialization, economic, and human capital development goals for private firms and for local, regional, and national units of government" (Gray, et al., 2013, p. 12).

In the absence of a definitive typology for CRCs, Gray et al. (2013) have developed a preliminary typology as an interim tool that can be used by program managers, policymakers and others with an interest in optimising or improving the effectiveness of new or existing CRC-type centres (Gray, et al., 2013). They also wish to "stimulate additional theory building and research on the processes and outcomes of CRCs" (p. 12). The preliminary typology for CRCs according to Grey et al. (2013) is said to have two dimensions: (*Dimension 1*) higher education (university) based vs. government/NGO-based,[8] and (*Dimension 2*) bilateral[9] vs. network-based. However, for the purposes of this literature review, the focus is on CRCs within universities only.

The dimensions represent key differences between CRCs and consequently lead to major variations within the elements of the three interconnected circles shown in Figure 20 (Gray, et al., 2013). These dimensions can be represented in matrix form (Figure 21 and Figure 22), where one is based on the definitive characteristics of CRCs (Figure 20) and the latter is based on expected CRC outcomes. Accordingly, a CRC that is university based is said to have access to infrastructure and be more likely to have translational research outputs (Gray, et al., 2013). University-based CRCs are also thought to

[8] An NGO is a non-government organisation.

[9] 'Bilateral' in this context refers to interactions between the CRC and just one other organisation.

have positive impacts on academics in terms of cultural shifts towards working with industry, albeit with some complexities around role strain (Gray, et al., 2013). Comparatively, a non-university-based centre is perceived to have better alignment with immediate commercialisation outcomes, be more responsive to industry requests and possess professional researchers and project managers, in contrast to universities (Gray, et al., 2013).

In terms of bilateral vs. network-based CRC collaboration as shown in Figure 21 and Figure 22: patent and product development with commercialisation outcomes is thought to be a high priority for bilateral collaboration, while general knowledge expansion with pre-competitive research and long-term translational research impact are considered the top goals for network-based CRCs, i.e. consortia collaborations (Gray, et al., 2013).

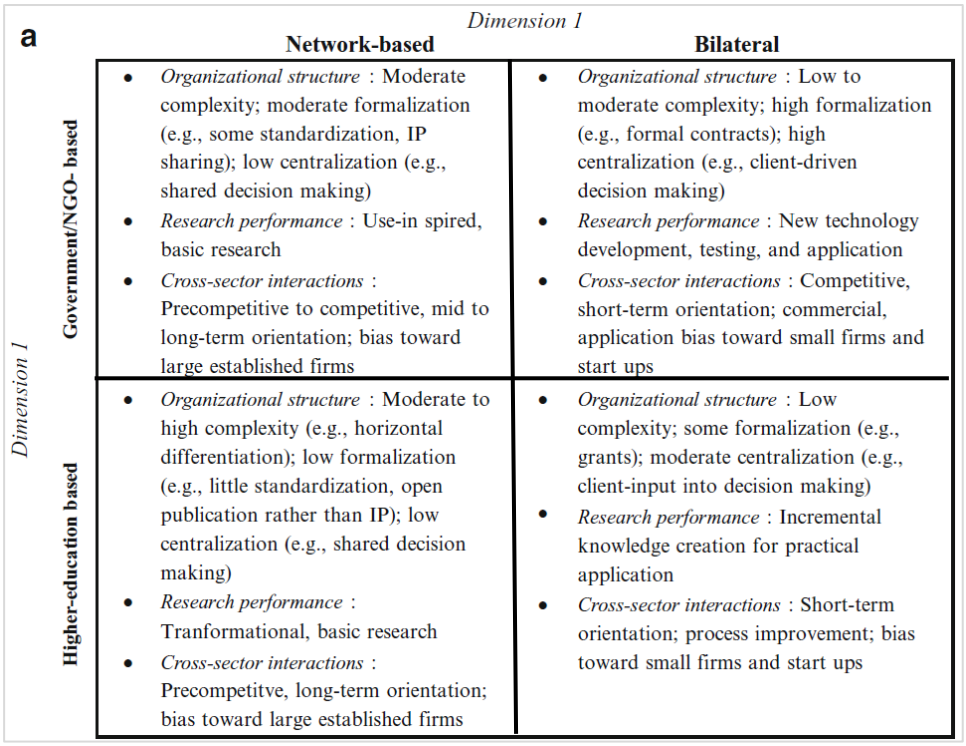


Figure 21 CRC preliminary typology based on the definitive characteristics of a CRC.

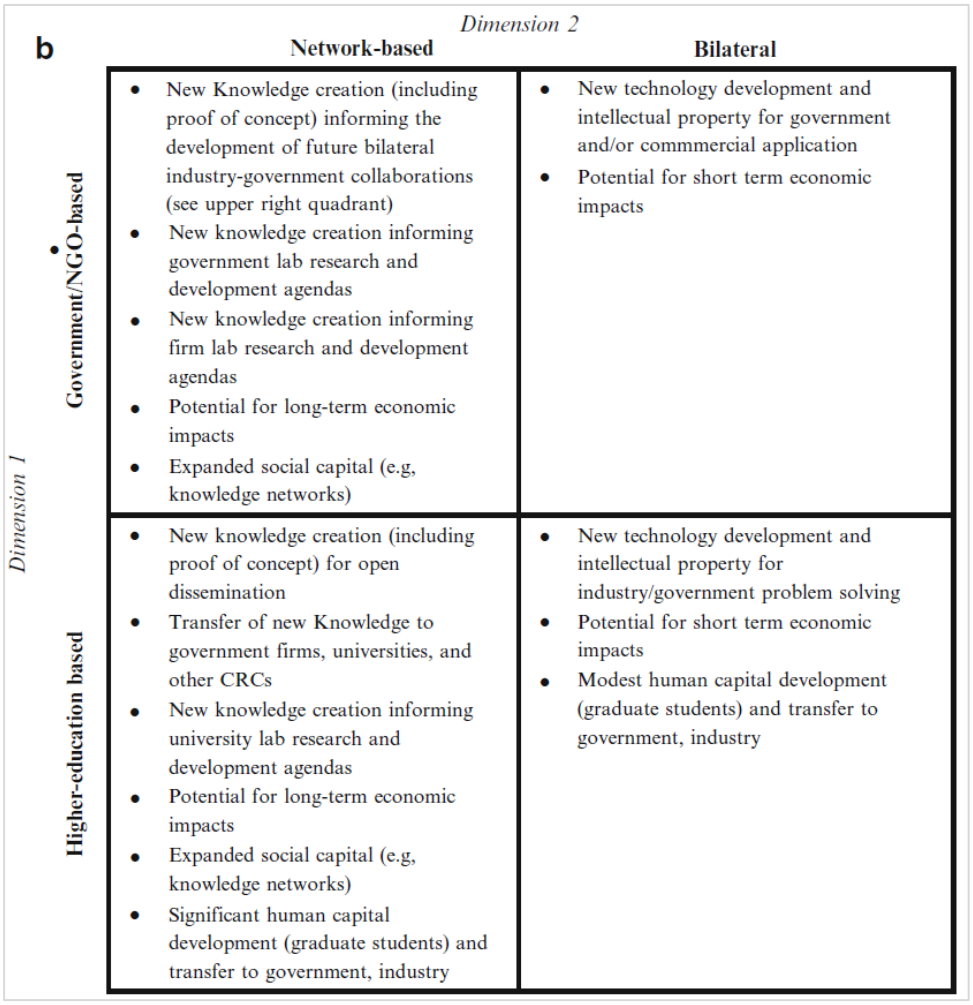


Figure 22 CRC preliminary typology based on expected CRC outcomes (Gray, et al., 2013).

Gray et al. (2013) indicate that their motivation for initiating the preliminary typology for CRCs is to encourage future research development into CRC typologies. They also suggest that future research might include consideration of hybrid CRCs that are both network-based and bilateral in terms of outcome generation (Gray, et al., 2013), i.e. high-impact research as well as commercialisation output.

This classification is observational, rather than instructive. While this typology is generally succinct, there are shortfalls in being able to use this for cross-comparing centres within universities or in developing an actual business model that can enable a framework for strategy and operations of an IA centre within a university.

Part C: Centre Models and Scope for Future Research

2.12 SUMMARY OF THEORETICAL CONCEPT CATEGORISATION FOR CENTRES

2.12.1 SCOPE FOR FUTURE RESEARCH

Lundequist and Waxell (2010) highlight a number of areas for future research: How does the governance of university–industry collaboration influence knowledge creation and economic development? Do these centres complement or substitute for policy efforts such as incubators and technology transfer offices? Do these centres undermine the long-term sustainability of research excellence?

Philbin (2011) states that studies should examine the management systems of centres across different countries. This is further emphasised by Boardman and Gray (2010), that there are differences across national models and actors, and within jurisdictions, sectors and funding agencies, all of which impact on research centres. These differences are contingent on public policy goals, funding structures, differences between scientific fields and industry sectors, factors operating at various organisation levels, management differences and the characteristics of individuals and stakeholders (Boardman & Gray, 2010). There is a call for greater discussion within both policy and scholarly communities about which factors truly differentiate the types of research centres, in order to develop a more comprehensive typology (Boardman & Gray, 2010).

Scholars have not produced much general knowledge of centres because the vast proportion of research is specific to evaluation efforts for a particular centre or centre program (Boardman & Gray, 2010). Hence, general examination of the organisational structures and personnel management practices within such centres is a regrettably neglected area of study. According to Boardman and Gray (2010), scholars have tended to develop distinct literature streams on a variety of centres, including innovation centres, IA centres, engineering research centres, university research centres and centres of excellence, that emphasise differences while ignoring or downplaying the common conceptual theoretical, policy, organisation and management issues that affect all these centres. Moreover, many scholars have also failed to recognise that centres are a social and organisational phenomenon. There needs to be a unified, coherent and integrated theory based on research of the processes and outcomes of collaborative research centres (Boardman & Gray, 2010).

Knowledge about these centres has been limited and inconsistent for four main reasons:

(1) Scholarly attention is modest and lags behind that for comparable topics, e.g. research parks and entrepreneurship

(2) The extant literature on cooperative centres is fragmented in part due to lack of definition clarity

(3) This is a complex and inherently challenging phenomenon to understand; and

(4) Scholars are still struggling to understand literature on collectivisation, research policy and open innovation (Boardman & Gray, 2010).

Sá (2008) postulates that centres also have inherent administrative and organisational issues, and suggests the need for universities to learn better ways of assessing performance, multidisciplinary collaboration, merit and governance. Additionally, there has been little research on the conditions under which industry opts to partner or not with centres given the increasing importance of an open innovation strategy in industry. This is a critical oversight in the literature (Boardman & Gray, 2010). In addition, the establishment of centres supposedly leads to the development of superior scientific and technical human capital, but studies have thus far neglected this area (Boardman & Gray, 2010).

Furthermore, many interpretations of collaborative centres focus on the role of interorganisational activities and processes in facilitating research and technology transfer. However, most studies address organisational characteristics not of the centres per se, but of the companies partnering with centres, including their structures, cultures and geographic proximity to the centres.

"Structure is important because it encompasses many aspects of a center we can deliberately create; it shapes activities and processes and thereby influences the achievement of organizational goals" (Gray & Walters, 1998, p. 60). This highlights a gap in the literature on the understanding of cooperative research centres as organisations in their own right (Boardman & Gray, 2010).

Lastly, a report by the Australian Council of Learned Academies (ACOLA), which followed a series of consultations between universities, government and industry, specifically states that Australia desperately needs a range of university–industry collaboration models, including research centres, networks, clusters, hubs and precincts (Bell, et al., 2015).[10]

There's a way to do it better – find it

– Thomas Alva Edison

2.13 CENTRE TYPES AND INHERENT CENTRE MODELS IN THE LITERATURE

The proceeding sections provide an overview of centre models as described in the literature spanning the Triple Helix actors: industry, academia and government (Etzkowitz, 2008; Leydesdorff, 2010).

2.13.1 CENTRE TYPES

Revisiting the Triple Helix model (Etzkowitz, 2008; Leydesdorff, 2010) presented in Chapter 1 for industry, university and government interaction in the KE and the Venn diagram introduced in Figure 2 (subsection 1.1.1), the following analysis considers some of the inherent centre models used in practice, although not specifically referred to as business models. In some instances, funding rules, articles and website content has been reviewed in order to understand and interpret the centre model underpinning it.

2.13.2 IAG CENTRES

According to Arnold et al. (2012), IAG centres (Figure 2) have an equal balance between academia and commercial outputs, i.e. 50:50. These typically include: publications, conferences, postgraduate researchers, industry income, collaborative projects, technology transfer, commercialisation investment, non-academic publications, patents, licences and company spin-outs (Arnold, et al., 2012). This clearly indicates an emphasis on research and innovation for IAGs.

However, IAG centres are thought to secure around 60–70% government funding, with medium to long-term use-inspired discovery research as the primary research type undertaken (Arnold, et al., 2012). Examples of such centres include:

- NSF ERCs in the USA;
- NSF Industry/University Cooperative Research Centres (I/UCRCs) in the USA;
- VINNOVA Competence Centres (now called VINN Excellence Centres (Verket För Innovationssystem , 2016a)) in Sweden;

[10] The researcher participated in one of the consultation workshops held in 2015.

- Australian Research Council (ARC) Industrial Transformation Research Hubs (ITRH) and Industrial Transformation Training Centres (ITTC); and
- Engineering and Physical Sciences Research Council (EPSRC) Centres for Doctoral Training, including the subset of Industrial Doctorate Centres (IDC) in the UK.

These types of centres, which are university hosted, have a quasi parent–child relationship with their host universities, with some of the dynamics described previously such as cost-sharing arrangements, and rewards and incentives (section 2.7). Clearly the hosting arrangements for IAGs within universities is important. No comparable IAG programs for centres exist in NZ. This confirms that there are many variations of IAGs in practice, but no simple method exists for visualising centre model variances for cross-comparison purposes.

There are also some hybrids, such as the Cooperative Research Centres (CRCs) in Australia. These CRCs are independent, standalone entities with an IAG membership model, i.e. they include multiple universities and research institutions in the membership, but are independent of universities, i.e. not a parent–child relationship with a single host university. Australian CRCs are generally set up as incorporated companies, to allow for flexibility with participants and reduce tax complexity (Anderson & Sciascia, 2013). Although some CRCs choose to operate and co-locate at universities for infrastructure access and support, they are not required to be university based (Miles, 2015; Australian Government Department of Industry, Innovation and Science, 2015b).

Arnold et al. (2012) explain that university-hosted centres cannot maintain the same scale when core program funding from government runs out. Centres may then be disbanded or become reliant on competitive research funding to remain sustainable. Indeed, “experience from these programmes clearly show that once the core funding by the government agency stops, the programmes and the centres collapse” (Alemany et. al, 2004, p. 10). This leads to a smaller scale of activity with an ad hoc research program consisting of mainly applied and short-term projects (Arnold, et al., 2012). There is thus a correlation between scale and core funding, and ultimately financial sustainability, for which no specific resolutions are proposed in the literature.

The findings from NSF ERCs suggest that, even when disbanded, an IAG centre leads to cultural change at the host university via increased awareness of industry engagement, multidisciplinary collaboration and external collaboration with other research organisations, as well as the acquisition of new research skills (Arnold, et al., 2012). A poignant view is held by some stakeholders of Australian CRCs who argue that, regardless of commercial return, industry–research collaboration is a ‘good thing’ via investments in research, capability development and relationship building (Miles, 2015). However, objectively there ought to be a focus on profitability, productivity and job-creation through such centres (Miles, 2015).

The NSF ERCs “provide an opportunity for national economic growth or contribute to the solution of a major societal problem that has a national and perhaps an international impact” (Lal, et al., 2007, p. 12). At the macro level, this suggests an emerging pattern for IAGs to drive towards economic benefit and societal impact, in addition to research output. It also aligns with the literature on the transition of research universities to entrepreneurial universities in the KE (sections 2.1, 2.2 and 2.3).

There are also marked differences between IAG centres around whether there is concerted effort in relation to educational imperatives or only a focus on research and innovation with industry. For instance, the VINNOVA Competency Centres in Sweden consider three key performance indicators (KPIs):

(1) Projects conceptualised between IA members lead to R&D and eventually to technology transfer

(2) Advancements made by the centre have enhanced the industry sector it serves; and

(3) Benefits to teaching and education have ensued (Alemany et. al, 2004).

The NSF ERC program in the USA shows a similar attitude, where supporting transformational research and innovation with industry, partnership development for research and education, developing education programs, promoting entrepreneurship and technology development are all regarded as highly desirable attributes for IAG centres (Lal, et al., 2007). This is a view also expressed for centres in NZ (Lawrence & Bodger, 2005; Lawrence & Bodger, 2006a; Lawrence & Bodger, 2008a).

Taking this a step further, an aspirational view for the enhancement of IAG centre impact includes improvements to education, recruitment, cultural change for IA partnerships, introduction of new products and services, and the economic value delivered to a country (Alemany et. al, 2004; Lawrence & Bodger, 2006b; Lawrence, et al., 2015; Lawrence & Bodger, 2008a). In Sweden, such centres are urged "to be funded without any other considerations or constraints" (Alemany et. al, 2004, p. 4), i.e. existing centres should be able to rebid for core government funding without having maximum time limits or being required to change focus (Alemany et. al, 2004).

An opposing view is that government funding should be limited to a maximum time period with no extension of funding (Miles, 2015; Australian Government Department of Industry, Innovation and Science, 2015b), such as the Australian CRCs with a proposed 10-year time limit (Miles, 2015). The NSF ERCs also impose a 10-year funding limit, followed by an additional year to transition towards shut-down or become self-sustaining (Lal, et al., 2007), while NSF I/UCRCs are given up to 15 years (Kroll & Dwertmann, 2015). The rationale here is that it "will make it clear that the focus should be on delivering tangible outcomes … without unnecessary distractions such as preparing for re-bids or transition planning" (Miles, 2015, p. 28). Fuelling this draconian view is the availability of government funding, which in turn imposes time limits on centres by government funding agencies (Lal, et al., 2007). Some funding agencies have gone to the extent of stating that "centres funded for a period longer than 10 years lost some of their 'creative spark' and thus longer life-spans were not optimal" (Lal, et al., 2007, p. 23). However, there is no specific rationale for determining the optimal lifespan for a centre (Lal, et al., 2007). Therefore, what is apparent in the literature is that the viability of IAG centres beyond government funding is a major concern.

Some centre models are able to exist without core government funding, i.e. independent of government, such as IA centres, for example the Electric Power Engineering Centre (EPECentre) at the University of Canterbury in New Zealand (Lawrence & Bodger, 2006a).

2.13.3 IA CENTRES

The other type of centre with both industry and academia is IA centres (Figure 2), such as the EPECentre. The EPECentre has an approach that spans the full innovation spectrum from outreach, education, training, consulting and testing services to product development, commercialisation, applied research, use-inspired research and basic research (Lawrence & Bodger, 2008b). It also possesses a portfolio of activity under three key pillars: (1) research; (2) education; and (3) industry interaction (Lawrence & Bodger, 2005).

One of the many unique attributes of the EPECentre is the use of centre research staff with industry experience to work on short-term projects (i.e. translational or consulting services) at the pace of industry with input from academic staff, while concurrently working on medium to long-term industrial research programs with participation from both industry and academics, and competitive government research grant funding (Lawrence & Bodger, 2006a). NSF ERCs undertake a similar approach, where centre staff pursue educational and knowledge transfer activity in addition to research and development (Lal, et al., 2007). Unfortunately not many IA or IAG centres take the approach of the EPECentre or the NSF ERCs, especially, when it comes to undertaking short-term fee-for-service consulting (Mullin, 2012). Some centre directors argue that this would dilute their research efforts, their need for intellectual involvement, and they prefer to work on projects that will generate new IP (Mullin, 2012). However, a minority believe that consulting is a practical component

of partnering with industry and suggest that the root cause for the resistance lies in the "traditional divide between pure and applied research" (Mullin, 2012, p. 32).

Mullin (2012) refers to a number of centres that have come to the realisation that legislative changes impact government funding streams and that consulting allows centres to "remain open to opportunities" (p. 33). Furthermore, a less traditional view is that consulting should not be viewed any differently to grant funding, where "contract work will pay the university's overhead … it is actually supporting the academic mission" (Mullin, 2012, p. 30).

2.13.4 IG CENTRES AND RESEARCH TECHNOLOGY ORGANISATIONS

Industry–government (IG) centres (Figure 2), also referred to as Research Technology Organisations(RTOs), are said to focus on short to medium-term applied R&D and technology and knowledge transfer, with around 30–50% of funding from government sources (Arnold, et al., 2012), for example, the Fraunhofer Institutes in Germany. The Fraunhofer Institutes draw on universities for academic capability as project subcontractors and many Fraunhofer staff hold adjunct positions at universities (Hauser, 2014). The Fraunhofer Society for the Advancement of Applied Research is the largest and leading research organisation in Europe (Fraunhofer Center for Manufacturing Innovation, 2010) and has been emulated by the Catapult Centres in the UK (Hauser, 2014) and also been recommended as a model for the Australian CRCs (Miles, 2015), although the CRCs were originally modelled on the NSF ERCs (Lundequist & Waxell, 2010) with some fundamental differences (e.g. being independent entities rather than centres within a university (Miles, 2015)). However, given that these centres are not IA or IAG and not within universities (i.e. not university led or university based), they are outside the scope of this thesis.

2.13.5 AG AND A CENTRES

Academia–government (AG) centres (Figure 2) are deemed to conduct mainly basic discovery research, with 100% of their funding coming from public sources (Arnold, et al., 2012); for example, the ARC Centres of Excellence (COEs) in Australia and the NZ Centres of Research Excellence (CoREs). The research focus of these centres is not on industry–university projects and hence they are outside the scope of this dissertation, as are A centres, which are internal university-only centres. Some AG and A centres engage with industry on an ad hoc basis.

2.13.6 I CENTRES AND G CENTRES

I and G centres (Figure 2) are industry R&D laboratories within companies, and government research laboratories within government research institutions, respectively. Therefore, I and G centres are outside the scope of this study.

The spectrum of centre types linking industry, academia and government (Figure 2) has much complexity and differentiation. However, the scope of this thesis is focused on IA and IAG centres that are within universities and also led by universities.

2.14 SYNTHESIS OF CURRENT MODELS FOR IA CENTRES IN UNIVERSITIES

There have been a number of research centre archetypes that have evolved over the last 30 years. Figure 23 depicts the development of various centres globally and shows which models have influenced each other. The highlighted blocks represent key mutations or archetype centres that have been analysed as part of this research. The focus group for this research is highlighted by the blue circle. This shows that for IA centres, the NSF I/UCRC program and the NSF ERC program in the USA are the archetype models.

The EPSRC Industrial Doctoral Centres (IDC) in the UK were the first to introduce focused IA doctoral training centres (EPSRC, 2011), according to the literature, while the ARC ITRH and ITTC programs in

Australia are the only active IA centre programs in ANZ which are university hosted and led (Australian Research Council (ARC), 2015). There are no such programs in NZ.

The EPECentre, which is part of this research study, is also highlighted, along with the Chemical and Plastics (C&P) Innovation Program at Monash University.

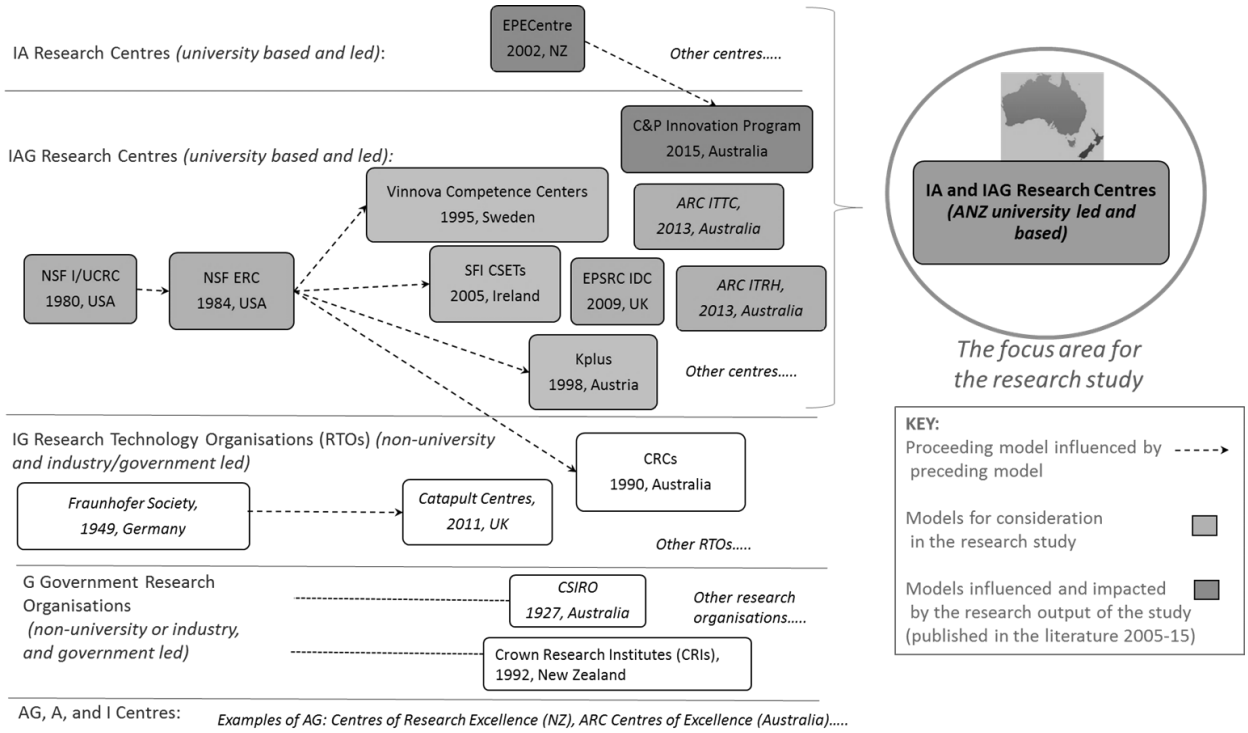


Figure 23 A sample of the research organisation landscape, mapping and highlighting the focus area for the research study: IA and IAG centres that are university based and led are in the top two sections, with centres of interest highlighted.[11]

A comparison of IA and IAG models is shown in Table 4, as interpreted by the researcher based on available literature. This comparative summary pertains to the centre types highlighted in Figure 23.

The NSF I/UCRC differs from the other centre approaches because of its IP sharing protocol, which makes it mandatory to share IP with all members of the I/UCRCs. The multi-university aspect is strongly emphasised in the two NSF centres in the USA, as well as longer periods of core government funding. Contrastingly, the ARC is more flexible on the multi-university stance but the likelihood is that multi-university bids would be favoured ahead of single-university bids to host a centre, and the period of funding is one-third less than what is offered in the USA (Australian Research Council (ARC), 2015). The ARC ITRHs and ITTCs are recent developments introduced in 2013, hence their literature is scarce, with the pilot set of ITTC and ITRH centres currently being operated out of various universities.

[11] Sources for dates: (National Science Foundation, 2016) (Australian Research Council, 2015) (Cooperative Research Centres Association, 2015) (Engineering and Physical Sciences Research Council, 2011) (Catapult, 2016) (Commonwealth Scientific and Industrial Research Organisation, 2016) (Science New Zealand, 2016) (Fraunhofer, 2016) (Verket För Innovationssystem, 2016b) (Science Foundation Ireland, 2016) (Biegelbauerm, 2007) (Lawrence, et al., 2015) (Lawrence & Bodger, 2005).

Table 4 Comparisons of IA and IAG centre models, as extracted by the researcher, based on the literature available.

Centre Model	Govt. fund period (yrs)	Main research resource staff?	Research & education: both?	Membership fees separate to research funding?	Dedicated manager?	Industry advisory board?	Multi-university?	IP sharing mandator with members?
NSF I/UCRC **(Gray & Walters, 1998)**	15	Postgrad students	Yes	Yes (minimum 6 members)	No (admin assistant)	Yes, research project focused; 2 per year	Yes	Yes
NSF ERC **(Lal, et al., 2007; Lewis, et al., 1996)**	10 + 1	Postgrad students, postdocs and centre R&D staff	Yes	Yes	Yes	Yes	Yes	No
EPSRC IDC **(EPSRC, 2011)**	4	Postgrad students	Yes	Yes	Yes	Yes, but not strictly industry	Yes	No
ARC ITRH **(Australian Research Council (ARC), 2015)**	5	Postgrad students, postdocs	No	No	Yes	Yes, research project focused	Yes	No
ARC ITTC **(Australian Research Council (ARC), 2015)**	5	Postgrad students, postdocs	Yes	No	Yes	Yes, research project/ training focused	Yes	No
EPECentre **(Lawrence & Bodger, 2006a)**	n/a	Postgrad students, postdocs and centre R&D staff	Yes	Yes	Yes	Yes, broad focus; 4 per year	No	No
C&P Innovation Program **(Lawrence, et al., 2015)**	3	Postgrad students	Yes	Yes	Yes	Yes, broad focus; 4 per year	No	No

According to Lal et al. (2007), the organisation, planning, management and function of IAG and IA centres can have a profound impact on "the productivity and efficiency of its researchers, how well faculty from different disciplines and fields of interest interact" (p. 24). Moreover, it can also determine the success of its research output to industry, as well as achieving "alterative missions like education and outreach" (p. 24). This indicates a narrative in the literature that puts research output ahead of education and outreach activity, but does emphasise the importance of a business model, although this term is not explicitly used in any of the literature in the context of IAG or IA centres.

2.14.1 STRATEGIC PLANNING DIRECTIVES FOR IA OR IAG CENTRES

Centres can take a roadmap-driven approach for their research agenda (i.e. technology-push) or an industry-directed approach (i.e. market-pull) (Lal, et al., 2007; Verganti, 2009b). In the roadmap-driven approach, the centre engages with stakeholders, industry partners and government (Lal, et

al., 2007). Contrastingly, in the industry-directed approach, a single industry partner or a collective of industry partners decides on the strategic management and research activity (Lal, et al., 2007).

Furthermore, with the single industry partner centre, the industry partner holds significant control, especially when the centre is dependent on the industry partner for funding (Lal, et al., 2007). This is in contrast to the roadmap-driven approach, where a centre responds to industry challenges and they plan together to achieve objectives (Lawrence & Bodger, 2005; Lawrence & Bodger, 2006a; Lawrence, et al., 2015). The literature appears to suggest that both technology-push and market-pull approaches are feasible for an IA centre's research agenda.

2.14.2 TOP-DOWN VS. BOTTOM-UP RESEARCH DIRECTIONS FOR IAG OR IA CENTRES

Some IAG centres such as NSF ERCs take a bottom-up or open approach, where the government funding agency does not dictate from above the areas of research it will fund – a rare approach (Lal, et al., 2007). The more common approach worldwide is top-down, where the government funding agency dictates which areas to focus on and how to structure the program, such as the Centres for Science, Engineering and Technology (CSETs) in Ireland (Lal, et al., 2007). Similar top-down approaches are prevalent in Australia's ARC ITRH and ARC ITTC programs (Australian Research Council (ARC), 2015). However, there are some centres that use a mixed approach (Lal, et al., 2007), such as the EPECentre in New Zealand, where it is bottom up for general R&D, but adopts a top-down approach for government-funded grants in partnership with industry (Lawrence & Bodger, 2008b; Lawrence & Bodger, 2005).

2.14.3 GOVERNMENT FUNDING FOR IAG AND IA CENTRES

According to Lal et al. (2007), program-level core operational funding for centres can vary across four approaches: (1) one-shot funding, where a single lump-sum grant is awarded at the start; (2) seed funding, where a smaller allocation is made for a centre to prove itself before graduating to full funding levels, e.g. CSETs in Ireland; (3) matched funding, where funding is a proportion of industry and other matched contributions, e.g. ARC ITRHs and ARC ITTCs (Australian Research Council (ARC), 2015); and (4) co-funding, which is similar to matched funding but there is joint strategic co-investment between government, industry and universities. On the other hand, IA centres do not receive core operational funding from government, but do leverage government funding through research grants (Lawrence & Bodger, 2008b).

2.14.4 NSF ERCS AND NSF I/UCRCS

According to Roessner (2015), the ERCs are the very large flagship centre program of the NSF ($3.6M per annum, requiring at least 4 universities to host). In the ERC model, 30% of the budget comes from industry members, 30% from the NSF, 10% from the host university and the balance from other government sources (30%) (Lewis, et al., 1996). ERCs have contributed significant value to US S&T advancement and education, as well delivering significant economic and societal benefits (Roessner, 2015), therefore the government funding agencies of a number of countries have emulated the NSF ERC approach, including Ireland (CSETs), Sweden (VINN Excellence Centres) and Australia (CRCs) (Lundequist & Waxell, 2010; Arnold, et al., 2012).

Similarly, the NSF I/UCRC program is the oldest program of its kind in the world and the original archetype for the NSF ERCs, albeit at a much smaller scale (Kroll & Dwertmann, 2015; DasGupta, 2013; Gray & Walters, 1998). The I/UCRC began as a single host-university centre model in 1980 and has expanded over time to become a multi-university centre model (Kroll & Dwertmann, 2015; Gray & Walters, 1998). It has remained "unaffected by government policy and politics" (Kroll & Dwertmann, 2015, p. 71), perhaps due to its relatively small size. However, unlike the ERCs, which cover a large spectrum of activity, the I/UCRCs are focused on use-inspired basic pre-competitive research and IA collaborative projects are predominantly undertaken by postgraduate students, as opposed to dedicated centre staff (Kroll & Dwertmann, 2015; DasGupta, 2013). In fact, more than

60% of all I/UCRCs ever funded since 1980 are still in operation, well beyond the 15-year limit on NSF funding, which can be regarded as significant (Roessner, 2015).

The I/UCRCs are catalysed by a small-scale seed investment by the NSF, which is less than 1% of the NSF's overall budget, and, other than progressive monitoring, it is largely left up to the centre director (a tenured academic) to generate industry revenue and university host support. In a similar way to ERCs, I/UCRCs also emphasise research and education as key pillars along with industry engagement (DasGupta, 2013; Kroll & Dwertmann, 2015; Roessner, 2015; Lewis, et al., 1996; Gray & Walters, 1998).

Part D: The Application of Business Models to Centres

2.15 INTRODUCTION TO BUSINESS MODELS

Business models have long been considered key across a number of industries from the commercial to the not-for-profit sectors and from start-ups to multinationals. Business models are like artwork in that many can recognise a good or bad one when they see it, but cannot quite define what it is (Ovans, 2015). This raises the question: What exactly is a business model? According to Ovans (2015), how people define a business model is subject to how they apply it. Drucker's theory of business (1994) is considered a dominant interpretation of the business model, although Drucker never explicitly used the term 'business model' (Ovans, 2015). In Drucker's (1994) view, there are many management techniques out there for business from corporate downsizing and quality management to benchmarking. However, he asserts that these are primarily 'how to do' tools for business, designed to do differently what is already being done, and not 'what to do' tools, which are at the heart of the real challenge facing business (Drucker, 1994).

This also links to what is called evidence-based management (Pfeffer & Sutton, 2006) when deciding on business models and strategy, which in turn guides business decision-making via a business plan. Pfeffer and Sutton (2006) stipulate:

> Business decisions, as many of our colleagues in business and your own experience can attest, are frequently based on hope or fear, what others seem to be doing, what senior leaders have done and believe has worked in the past, and their dearly held ideologies – in short, on lots of things other than the facts. (Pfeffer & Sutton, 2006, p. 5)

Pfeffer and Sutton (2006) state that poor business practice, i.e. business plans underpinned by unsuitable business models and strategy, come down to three factors: (1) casual benchmarking; (2) doing what seems to have worked in the past; and (3) following deeply held, unexamined ideologies (Pfeffer & Sutton, 2006).

Taking each of these factors in turn:

(1) Casual benchmarking pertains to the mindless imitation of another organisation without understanding how and why their business model and strategy work – the main issue being that people copy the most obvious and visible elements, e.g. a competitor's website (Pfeffer & Sutton, 2006).

(2) The problem with doing what seems to have worked in the past is that a new situation may be different to an old situation, but the same solution is blindly applied (Pfeffer & Sutton, 2006; Finkelstein, 2003).

(3) Ideologies and beliefs are the hardest to change, e.g. an organisation must go to the market and recruit a superstar to be successful, even when there is no guarantee that past performance will match future results (Pfeffer & Sutton, 2006).

A business model is conceptual in nature and represents a type of architectural blueprint for a business operating in a specific industry. In other words, it is analogous to the fundamental structure of a business within an industry sector, with each industry sector operating off business models suited to their specific industry, such as telecommunications service providers with their bundled phone and internet packages, and electricity retailers with 'pay as you go' (Ovans, 2015). However, business models can change as old industries evolve and new industries are born.

In Magretta's (2002) interpretation, a business model is a system that describes how the components of a business actually connect together, i.e. analogous to the structure of a machine and how it is

fitted together to function for a purpose. Business models extend to being the management equivalent to the scientific method, where one starts with a hypothesis which can be tested in practice to develop a working model (Magretta, 2002). She goes further to state that, when a new business model changes the dynamics of an industry, it can provide a strong competitive advantage for those that adopt it. For example, when computer manufacturers only sold through retailers, Dell created a rapid direct-to-customer approach and introduced a new type of product delivery (value chain) that was considered a 'game changer' for the computer industry (Magretta, 2002). This business model has since been replicated and enhanced by the likes of Apple in 2001 with the launch of the Apple store.[12]

Table 5 presents some basic examples of well-known business model concepts from the revenue perspective and used by a number of different industries. There is a diverse number of ways to view a business model. This is further discussed in the sections ahead. According to Osterwalder (2004), the term 'business model' is used by everyone from executives to analysts and journalists. However, they "never really had a clear idea of what it meant" (p. 23).

Business models can be combined for various new industries. For example, an affinity club model can be combined with a subscription and a freemium model to produce a bespoke business model suited to the online music industry. The online music company Spotify uses this model, which provides digital music services on a freemium and a subscription basis, and then pays royalties to record companies.[13]

Table 5. Examples of various types of Business Models used by different industries (modified from source: HBR.ORG).

Business model	**How the model works from a revenue perspective**	**Industry examples**
Affinity club	Pay royalties to another organisation for the right to sell your product exclusively to their customers.	eBay; Trademe
Brokerage	Bring together buyers and sellers, charging a fee per transaction to one or another party.	Century 21 Real Estate
Bundling	Package related goods and services together.	Telstra (bundles internet, phone and cable television together as packages)
Cellular (mobile) phone	Charge different rates for discount levels of a service.	Vodafone
Crowdsourcing	Get a large group of people to contribute to an initiative in return for an indirect beneficial outcome or recognition.	Wikipedia
Freemium	Offer basic services for free and charge for premium services.	LinkedIn
Leasing	Rent, rather than sell, high-margin, high-priced products.	Hertz

[12] Source: http://www.macworld.com/article/1159817/computers/first2applestores.html
[13] Source: http://www.spotifyartists.com/spotify-explained/

Low-touch	Lower prices by decreasing service.	IKEA
Pay as you go	Charge for actual metered usage.	Energy retail companies, e.g. Origin Energy
Razor/blades	Offer the high-margin item below cost to increase volume sales of the low-margin item.	Epson (printers and ink); Gillette (razors and blades); Nespresso (machines and pods)
Reverse razor/blades	Offer the low-margin item below cost to encourage sales of the high-margin companion product.	iPhone with iTunes (apps)
Product to service	Rather than sell a product, sell the service the product performs.	Flexicar
Subscription	Charge a subscription fee to gain access to a service.	Netflix
User communities	Grant members access to a network, charging both membership fees and advertising.	Angie's List (local business finder website)

2.16 BUSINESS MODEL VS. STRATEGY

The goal of this research is to present a recommended business model for IA S&T centres in ANZ universities. This is not to be confused with the development of a recommended strategy for IA S&T centres, which is beyond the scope of this research. However, it is important to understand the distinction between business model and business strategy.

Michael Porter, whose theories are central to strategic management, states that the basic step in business viability is the business model (Magretta, 2012). This helps an organisation focus on the fundamental questions: How are we going to make money? What will costs look like? Where will the revenue come from? and How can we be profitable? (Magretta, 2012). In other words, in Porter's view a business model lens helps the exploration of different ways of obtaining revenue and managing costs (Magretta, 2012). This is close to the perspective that is shared by Drucker (1994) in his theory of business (Ovans, 2015). The business model is essentially a description of the way that a business runs (Ovans, 2015).

According to Owens (2015) and Magretta (2002), the terms 'business strategy' and 'business model' are incorrectly interchanged and often confused. Distinct from your business model, your strategy explains how you will beat the competition in your business (Magretta, 2002). Furthermore, Porter argues that this goes beyond the basic viability of a business asserted by a business model and asks How can we make more money than our rivals? and How can we develop and sustain the competitive advantage over time? (Magretta, 2012).

This opens the door to why strategy matters also to IA S&T centres in universities. According to Porter and Lee (2015), some businesses in certain industries (e.g. health care) can get by without a real strategy, as long as the business is in demand, supported by operational effectiveness (Porter & Lee, 2015). However, the era of having a default strategy reliant on market dominance and scale of operation is coming to an end, as the cost of doing business increases over time (Porter & Lee, 2015). Nonetheless, every organisation inherently has a business strategy, whether or not its leaders and managers contemplate what this is or recognise its existence (Magretta, 2002).

2.16.1 THE FIVE FORCES MODEL

A good brand reputation is no longer enough and customers are looking for value (perceived) for each and every product produced and service provided (Porter & Lee, 2015). In order to rethink the meaning of strategy, Porter's 1979 five forces model provides a conceptual view of what shapes competition in an industry setting (Figure 24). However, the configuration of the fives forces can differ from industry to industry (Porter, 2008), which applies equally to IA S&T centres in universities. The elements of the five forces model can be summarised as follows:

- **Threat of new entrants** – new entrants aim to win market share and put pressure on existing businesses but there are barriers to entry, such as supply-side and demand-side economies of scale, capital requirements, quality advantages, access to distribution channels and restrictive government policies (Porter, 2008).
- **Bargaining power of suppliers** – the dependence of suppliers on the business, impediments to switching suppliers and no substitutes available for what the supplier group provides, e.g. pilots are suppliers to the airline industry and there are no proxies for professional pilots (Porter, 2008).
- **Bargaining power of buyers** – buyers can demand more value, request higher quality, push for lower prices, i.e. price sensitivity; buyers can have high or low switching costs (Porter, 2008), i.e. to swap to another seller.
- **Threat of substitutes** – a non-obvious competitor that performs a similar service or product offering in a different format that may also be acceptable to a buyer as a substitute for what a business offers, e.g. videoconferencing as a substitute for travel (Porter, 2008).
- **Rivalry among existing competitors** – price discounting, which is destructive to the profitability of the whole industry; new products or services, advertising and service improvements to offer more value, e.g. features, service support, delivery time, and brand image; rivalry can be positive if competitors demonstrate complementarity (Porter, 2008).

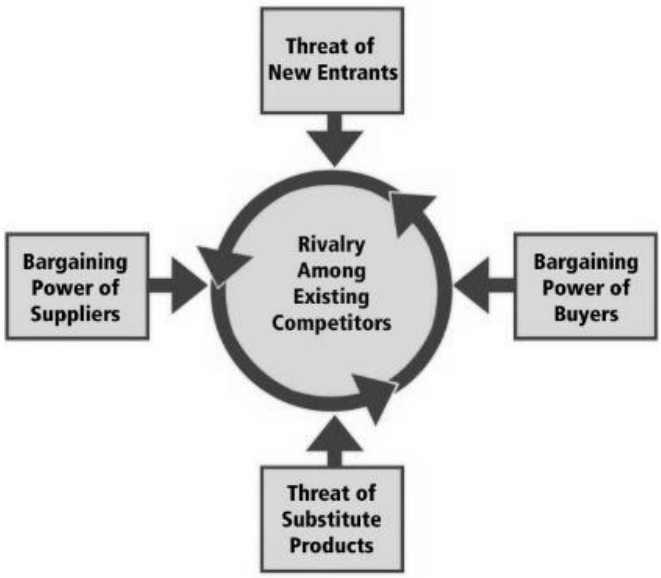


Figure 24 Porter's five force model that shapes industry competition (adapted from source (Sustainability Accounting Standards Board , 2014))

There are further pointers on strategy that are of relevance to IA S&T centres, such as the importance of both the supply side and the demand side in developing a competitive advantage, which requires a value-chain approach in Porter's view (Magretta, 2012). Also, according to Porter (2008), it is not about making everyone happy, benchmarking against others by overemphasising financial trends and projections, or blindly copying a competitor (Magretta, 2012). This echoes the perspective argued by

Pfeffer and Sutton (2006) on what constitutes poor business practice without an evidence base, as described earlier.

Furthermore, a concept that is often believed is that competition may not exist in certain industries or situations; however, Porter points out "there is no such thing as a market where competition is irrelevant, as nice as that might sound" (Magretta, 2012, p. 14).

Sceptics have tried to scrutinise the five forces model for its lack of focus on the customer (Forbes, 2012; Somers, 2013). However, scholars have argued that the five forces model is a starting framework for developing strategy to ensure that the key elements for competitive advantage are addressed (Northwestern University, 2013).

In terms of actually developing a strategic plan, Porter advices that a coherent strategic plan should involve the whole team responsible for a business working together, rather than dividing up components of a plan into separate functional plans that get stitched together to be called a strategy (Magretta, 2012).

2.16.2 SYNTHESISING THE DIFFERENCES BETWEEN A BUSINESS MODEL, STRATEGY AND PLAN

From business models and business strategy to the KE, business models and strategy are crucial for growth. The KE "is faced with new challenges following the changing relationship between the creation of business value from the optimisation and exploitation of knowledge as the new key economic resource" (Bang, et al., 2010, p. 616).

The notions of strategy and business model are not the same constructs; there is also a difference between strategy and tactics (Casadeusus-Masanell & Enric Ricart, 2009):

> Business model refers to the logic of the firm, the way it operates and how it creates value for its stakeholders. Strategy refers to the choice of business model through which the firm will complete in the marketplace. Tactics refers to the residual choices open to a firm by virtue of the business model that it employs. (Casadeusus-Masanell & Enric Ricart, 2009, p. 2)

This is made clear by the diagram in Figure 25, where strategy is framed as a two-stage process (Casadeusus-Masanell & Enric Ricart, 2009). In stage 1 the organisation picks the business model, and stage 2 is when tactics are determined in order to drive in a certain direction (Casadeusus-Masanell & Enric Ricart, 2009), i.e. the strategic plan and the tactics that follow to operationalise it.

Figure 25 The two-stage process from strategy to tactics with a chosen business model (source: (Casadeusus-Masanell & Enric Ricart, 2009)).

The implications of the business model concept for strategy and operations can be regarded as selecting a business plan to suit the strategy, which in turn determines the operations.

A simple analogy is to view strategy as the navigation device that plots the destination and milestones to reach (the 'where'), the business model as the vehicle to get there (the 'what'), which can be configured and preselected to fit the desired destination, and the operations manual and operation of the vehicle is the business plan execution by the leaders of the organisation (the 'how').

This simple analogy aligns with the way Drucker (1994) describes business (i.e. having 'where', 'how', and 'what' to do tools) as discussed previously (section 2.15); Drucker also points to the lack of 'what to do' tools, i.e. business models. This is further illustrated by the diagram in Figure 26 using the vehicle analogy introduced.

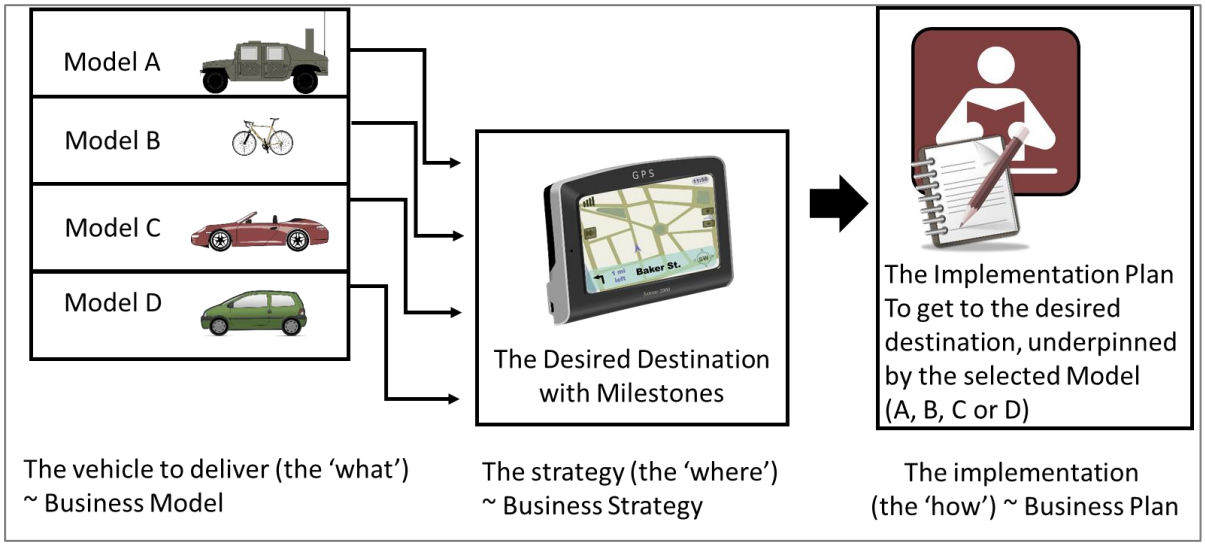


Figure 26 From a business model to a business strategy, which leads to a business plan (adapted from image source: (Pixabay, 2016)).

2.17 BUSINESS MODEL FOR COLLABORATIVE CENTRES

The rationale for developing a recommended business model for collaborative centres in ANZ universities is threefold: (1) it defines a business model from a structural, typological and economic perspective to add value to the KE, when one currently does not exist in the literature; (2) it enables the development of a typology for cross-comparing research centres in universities, which in turn can be converted into a management toolkit for accessing and doing a structural health check on centres; and (3) it establishes a framework or blueprint model for IA centres, to build towards a bespoke strategic plan and subsequently an operational business plan to deliver on the strategy.

There is an international debate regarding the challenges and opportunities for unifying the concepts of the business model (Velu, et al., 2015); the definition includes:

- Value conceptualisations through configurations of attributes, activities and representations
- Business models seeking to identify bespoke configurations of attributes
- The level of disruption as the level of change to customer engagement via the business model

There are many variations used to describe business models, everything from a blueprint, an abstraction, a description, a conceptual tool and a structural template to a method, a framework and a hypothesis (Universalia, 2013). A key question is how elements of these can be mapped to build subsequent tools and theories (Osterwalder, 2004). One perspective is to use imagery to map out a business model, such as the business model tool shown in Figure 27 developed by Osterwalder and

Pigneur (2009). This tool, called the business model canvas, is the first of its kind and the market leader used by commercial businesses such as IBM, 3M and Deloitte (Osterwalder & Pigneur, 2009).

However, in its current form it is not suitable for IA centres within universities, because of the complexities associated with operating centres within a university environment and IA centres' spanning (section 2.3) industry, academia and government (Figure 2). Some of the complexities, as indicated in previous sections (sections 2.5–2.10), include balancing the public good and commercial mission of universities, complex mix of funding streams, internal management structures, and adaptable role-reversing of customer and partner dynamics in IA collaborations. These complexities are discussed in detail in the results and discussion (Chapter 4).

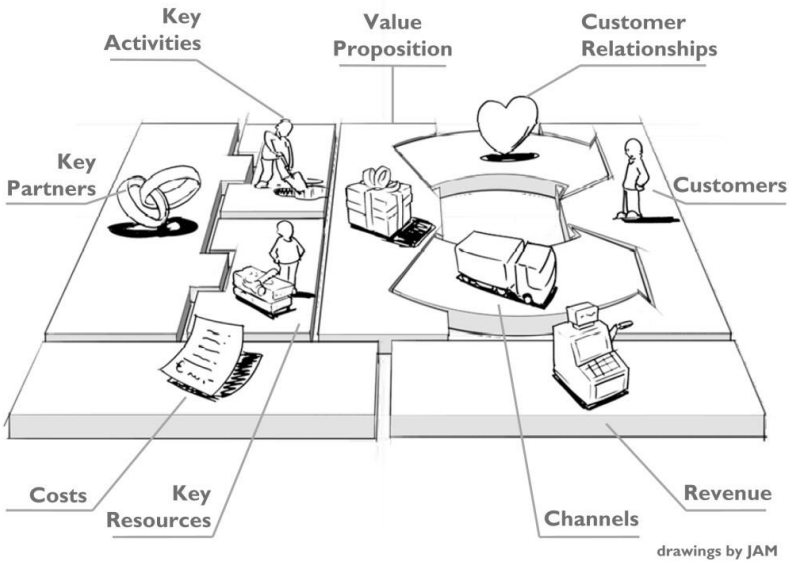


Figure 27 The business model canvas (source (Osterwalder & Pigneur, 2009; Entrepreneurial Spirit Exchange, 2015)).

Ultimately, "business models provide opportunities to frame how value can be realised from existing assets, and can also provide conceptualisation of new applications" (Velu, et al., 2015, p. 3). Hence, for the purposes of this dissertation the researcher follows the interpretation of a business model for an S&T IA centre incorporating a structural blueprint, with engineered components and an integrated economic engine. This will be realised as a conceptual, four-dimensional (4D) business model where each component of the model has: (1) a structural; (2) an interactional; (3) a financial; and (4) an activity perspective (Chapter 5). From a value realisation perspective, IA centre outcomes ought to deliver value to the KE via the entrepreneurial university (section 2.3).

Even though an organisation may have the perfect business model, business strategy and plan, it will be ineffective, indeed irrelevant, if the strategy and business plan are not executed. This would turn it into a knowing–doing gap situation, as coined by Pfeffer and Sutton (2000). Pfeffer and Sutton argue that organisations often make the mistake of assuming that once they write down what they need to do, "it will be used appropriately and efficiently" (p. 16). There is also the issue of negative people who get in the way of executing a strategy once the business model is determined. "One of the best ways of sounding smart is to be critical of others' ideas" (Pfeffer & Sutton, 2000).

Inaction and negative people issues are likely to have an effect on IA centres within the university environment. It is up to the leadership of the centres to mitigate such issues, since "action counts more than elegant plans and concepts" (Pfeffer & Sutton, 2000, p. 251).

2.18 TOWARDS THE RECOMMENDED BUSINESS MODEL FOR IA CENTRES

In terms of motivation for the research, it is clear that no business model exists for university led and based S&T IA centres in the literature (sections 2.5–2.14). The following section highlights the opportunities, the challenges and the implications of introducing a business model for IA centres within universities, and stipulates the key research questions for the thesis.

2.18.1 IMPLICATIONS FOR A CENTRE BUSINESS MODEL

Opportunities: The opportunities presented for developing a business model (Velu, et al., 2015) for IA collaborative centres in universities include: the generation of impact by translating value between the industry and the university sectors; and the self-sustainability of the IA centre by being able to respond to change within its operating environment (i.e. entrepreneurial universities). An appropriate business model can also challenge the existing centres within universities, and provide a robust platform for new centres that can be used to cross-compare centres in universities, allowing future research on theory development.

Challenges: Introducing the recommended business model for centres into the university environment takes it beyond the realm of ordinary change within a university (Velu, et al., 2015). Business model innovation (BMI) transcends traditional boundaries and the key challenge is to identify the classification scheme (Velu, et al., 2015).

BMI is a dynamic concept where "longitudinal research is required" (Velu, et al., 2015, p. 4). Therefore, according to Velu et al. (2015), BMI requires close researcher–subject interaction over a significant period of time, thus requiring the dual capability of being able to innovate a business model while testing and improving on the model's logic. It essentially means adapting the business model to add value in response to change, threat or opportunity.

The research for this thesis has been conducted over a prolonged sampling period from 2005 to 2016 (i.e. longitudinal). During this time period, the researcher was a participant-observer of over 20 centres and IA collaborations across three ANZ universities and was able to conduct data collection, analysis, and testing and validation of the recommended business model (see Chapter 3). Furthermore, according to Velu et al. (2015), this approach represents a 'living laboratory' initiative "to test the opinions, acceptability, and viability of BMI, and to explore the impact of business model theory" (Velu, et al., 2015).

Implications for centres in universities: Based on the findings of Velu et al. (2015), the creation of a recommended business model for collaborative IA centres within an ANZ university will:

- Promote visibility for societal and economic impact through centres
- Foster and guide IA collaborative activity for centres using a common framework
- Inform new centres of appropriate business models and assist existing centres to improve their business models
- Assist decision-makers such as funding agencies and government on the applicability of a generalised theory beyond IA boundaries for IA S&T centres
- Support the future development of KPIs for university centres in entrepreneurial universities, using the typology for cross-comparison and for the structural diagnosis of centre models, i.e. a health check toolkit for centres.

Implications for IA collaboration in centres: The development of a recommended business model for IA centres, based on the general principles of Velu et al. (2015), could lead to:

- Opportunity for improved technology and knowledge transfer from centres to industry, with the adoption of sensible structures and leadership
- Ability to develop new capabilities underpinned by the business model for centres
- Ability for the centres to be resilient to changes in the innovation ecosystem.

Implications for government: As far as government is concerned (Velu, et al., 2015), a business model for IA centres in universities and a typology for cross-comparing centres can:

- Help drive improvements to existing and new grant program models for IA centres; there is such a call to action in Australia (Bell, et al., 2015)
- Stimulate cooperation between government, industry and universities for new paradigms in economic and social development
- Promote entrepreneurship between industry and universities
- Educate industry and university on its use for value creation via centres
- Use the typology and cross-comparison toolkit for assessing the structural integrity of S&T centres within the innovation landscape of a country in its transition to the knowledge economy; for example, the cross-comparison of university S&T centres within ANZ or various international boundaries, industrial sectors and research themes.

2.18.2 THE KEY RESEARCH QUESTION

The key research question for the thesis:

What is the recommended business model for industry–academia S&T centres within ANZ universities?

Sub-questions:

- What are the types of industry–academia S&T centres within universities in ANZ?
- How many industry–academia S&T centres are there in ANZ universities?
- Why are industry–academia S&T centres within universities important to ANZ?

CHAPTER 3. RESEARCH DESIGN AND METHODS

3.1 INTRODUCTION TO RESEARCH DESIGN

Chapter 2 has elaborated on the theoretical framework for the research and the research questions. This has paved the way for the research conceptual framework, which is primarily a theory of the phenomena under investigation (i.e. IA S&T centres within ANZ universities) constructed by the researcher and progressively refined over the course of the research (Miles, et al., 2014; Maxwell, 2013), as shown in Figure 28.

The conceptual framework identifies the research map of the elements to be investigated in order to answer the research question: the key factors, variables or constructs, and the linkages between them (Miles, et al., 2014). This chapter outlines the research design (or research paradigm), which includes the research methodology and method, as well as indicating the instruments used for data collection and how the data has been processed.

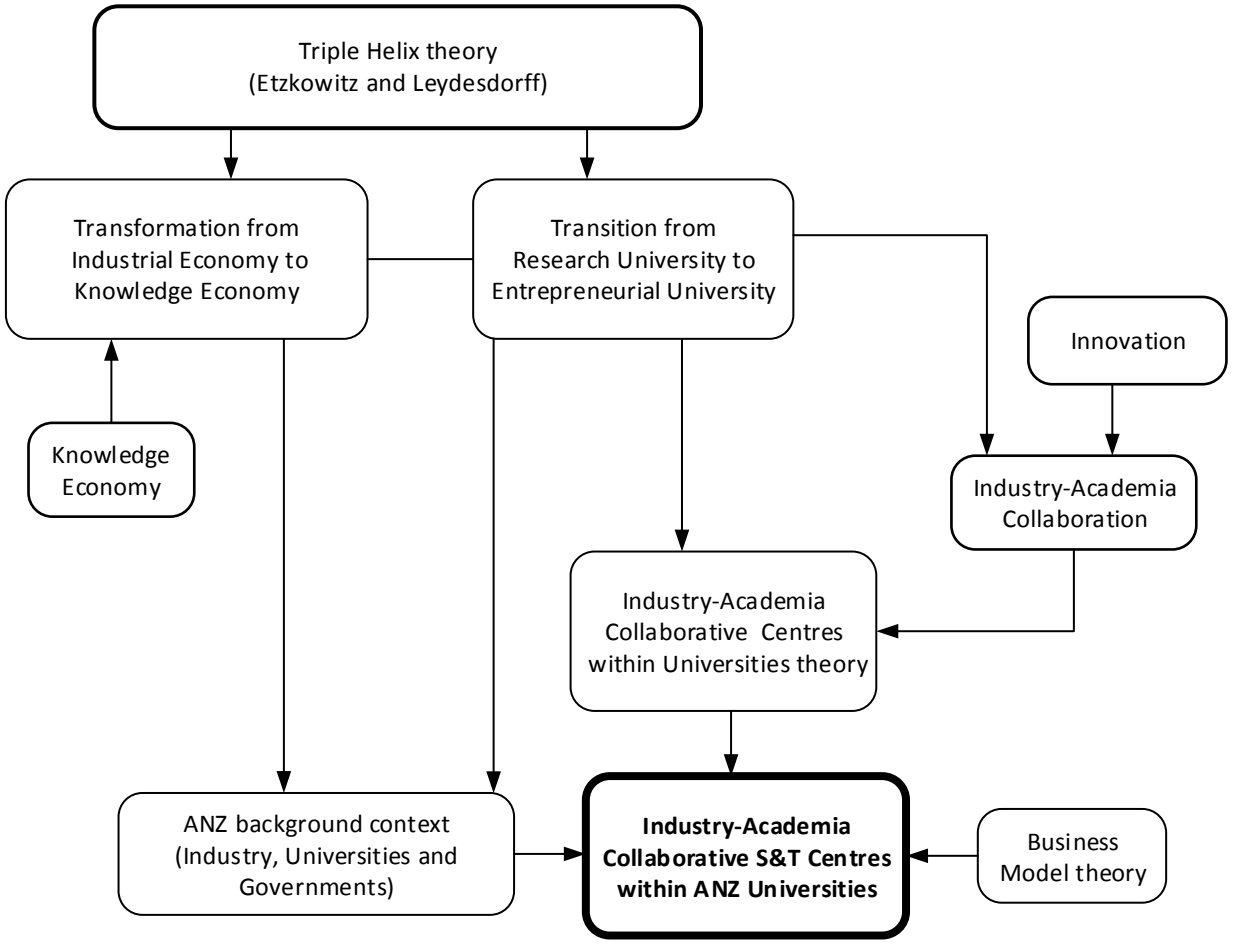


Figure 28 The refined conceptual framework post-literature review.

3.2 RESEARCH METHODOLOGY

This thesis follows a mixed-method approach whereby qualitative and quantitative methods have been intermixed to address the key research question (What is the recommended business model for industry–academia S&T centres within ANZ universities?). The use of mixed methods has become

increasingly common in recent years and it is considered a fundamentally relevant and appropriate method (Mason, 2006; Bryman, 2006). Research in general can be segmented into three distinct approaches: quantitative, qualitative and mixed methods, also referred to as multi-method, multi-strategy or mixed methodology (Bryman, 2006).

There is a call in the literature to provide a classification of the various mixed-method approaches into a typology (Creswell, et al., 2003). However, Bryman (2006) indicates that the range is so varied that the exercise of classifying typologies is futile. Bryman (2006) argues that there are relatively few guidelines on how to undertake mixed-method approaches. One solution has been provided by Mason (2006), who proposes practical strategies for utilising mixed-method research approaches.

Mason (2006) describes six strategies using: (1) rhetorical logic; (2) parallel logic; (3) integrative logic; (4) corroborative logic; (5) multidimensional logic; and (6) no intrinsic logic. Mason (2006) suggests that researchers engaging in mixed methods needs to have a sense of logic and purpose, because this will underpin the mixed-method approach to be used in order to analytically link data in a meaningful way. Bryman (2006) states that when mixed methods are employed, the practice, i.e. the method, does not always tally with the reasons given for the approach, i.e. the methodology. Hence, Mason's (2006) logic-based approach is a practical approach for the mixing of methods by linking different forms of qualitative and quantitative data. These strategies are broadly summarised in Table 6.

Table 6 Summary of the six strategies for mixed-method application as described by Mason (source: (Mason, 2006)).

Mixed-method strategy type	**Mixing method description**
1. Rhetorical logic	For a close-up illustration of a bigger picture or for background; researcher uses either qualitative or quantitative data to supplement an explanation; easy to do, but lacks true mixed-method application benefit.
2. Parallel logic	To ask and answer differently conceived or separate questions. This approach overall is essentially based on the idea of the co-presence of multiple methods, rather than their integration; easy to do, but limited benefits because there is no attempt at integration i.e. methods stay parallel.
3. Integrative logic	To ask questions about connecting parts, segments or layers of a social whole; tries to tackle mixing or linking data head on, but requires difficult integrative analysis of the different forms of data collected; difficult to do and benefits are limited by the ability of the researcher to integrate data sets.
4. Corroborative logic	To achieve accurate measurement through triangulation. This is the most common approach for mixed methods, typically referred to as triangulation, where different forms of data and method are used to corroborate what they are measuring; difficult to do correctly and with limited benefits because different methods and approaches rarely corroborate each other straightforwardly.
5. Multidimensional logic	To ask distinctive but intersecting questions; recognising that the social world and the issues and problems we seek to research are multidimensional and that dimensions exist in an uneasy tension, rather than being neatly integrated within one dimension; difficult to do but significant promise for enhancing social science explanation.
6. No intrinsic logic	An opportunistic approach to mixing methods; the key challenge is for the researcher to find a logic that provides an effective way of proceeding; difficult to find such a logic and put into practice; ultimately a 'luck of the draw' type of approach in terms of findings.

For the purposes of this research, it was decided that the multidimensional logic approach (Table 6) was the most appropriate and suitable. This methodology is based on the premise that real-world complexity is indeed multidimensional:

> It means that instead of ultimately producing one integrated account or explanation of whatever is being researched (integrative logic), or a series of parallel accounts (parallel logic), one imagines instead 'multi-nodal 'and 'dialogic' explanations which are based on the

> dynamic relation of more than one way of seeing and researching. This requires that researchers factor into their accounts the different ways of asking questions and of answering them. (Mason, 2006, p. 10)

This approach of multidimensionality requires that researchers think creatively 'outside the box' with respect to the scope of knowledge and the study of reality, leading to what Mason (2006) describes as 'creative tensions', which are considered valuable for enhancing research explanation. Hence, this requires the meshing or linking of qualitative and quantitative methods, rather than integrating and comparing methods, aligning with the strategies offered by Mason (2006). Hence, the research method follows a line of enquiry where the research is driven qualitatively for the mixing of methods. This presents the opportunity to provide enriching answers to the research question in a multidimensional way, rather than being limited by a one-dimensional qualitative approach on its own. Therefore, with the multidimensional approach, standard qualitative methods like Grounded Theory (Charmaz, 2014; Birks & Mills, 2011) can be applied in a modified way.

Mason (2006) points to two principles. First of all, given that the research topic area is on business models for IA collaborative S&T centres within ANZ universities, this is indeed multidimensional, tied to social experience and lived reality, and it would be inadequate to view this topic along a single dimension (Mason, 2006), such as the lone viewpoints of actors (e.g. individuals from industry and universities) in the ecosystem, without taking into consideration such things as the policy framework, strategic plans and performance metrics for ANZ.

The second principle is the premise that multidimensionality is enacted simultaneously on macro and micro scales, which again aligns with the rationale for considering dimensions, within the context of S&T centres within universities, to areas such as performance metrics and policy, management practice and technology transfer (practice and performance metrics). Hence, the research method has to recognise and reconcile the connections between these multidimensional domains, which requires approaching the research problems with an innovative and creative smorgasbord of non-restrictive data sources (Mason, 2006). Therefore, rich data can be generated from interviews, field observation, textual analysis, surveys, demographic statistics, websites, brochures, reports, policy documents, strategic plans and economic data. Furthermore, using a multidimensional approach that interlaces macro and micro evidence addresses the concern that theories that are not well founded empirically ultimately may have limited explanatory capacity (Mason, 2006).

By using a qualitatively driven mixed-method methodology with multidimensional logic, the research question can be addressed in a meaningful and empirically well-founded way (Mason, 2006; Bryman, 2006). The research method used for this project is depicted in Figure 29 and Figure 30, which show the first layer of qualitative inductive enquiry, driven by fieldwork observations, followed by multiple iterations of mixed-method approaches within, i.e. Phases I–III, which is modified Grounded Theory (Charmaz, 2014; Birks & Mills, 2011) by the coding of case study results and field observations. This is determined on the principle that qualitative research has the explanatory edge in a wider sense compared with quantitative social research, which is about fixed, standard units of measurement, and measurement of trends, comparisons and prediction, which unfortunately can miss crucial explanatory factors (Mason, 2006).

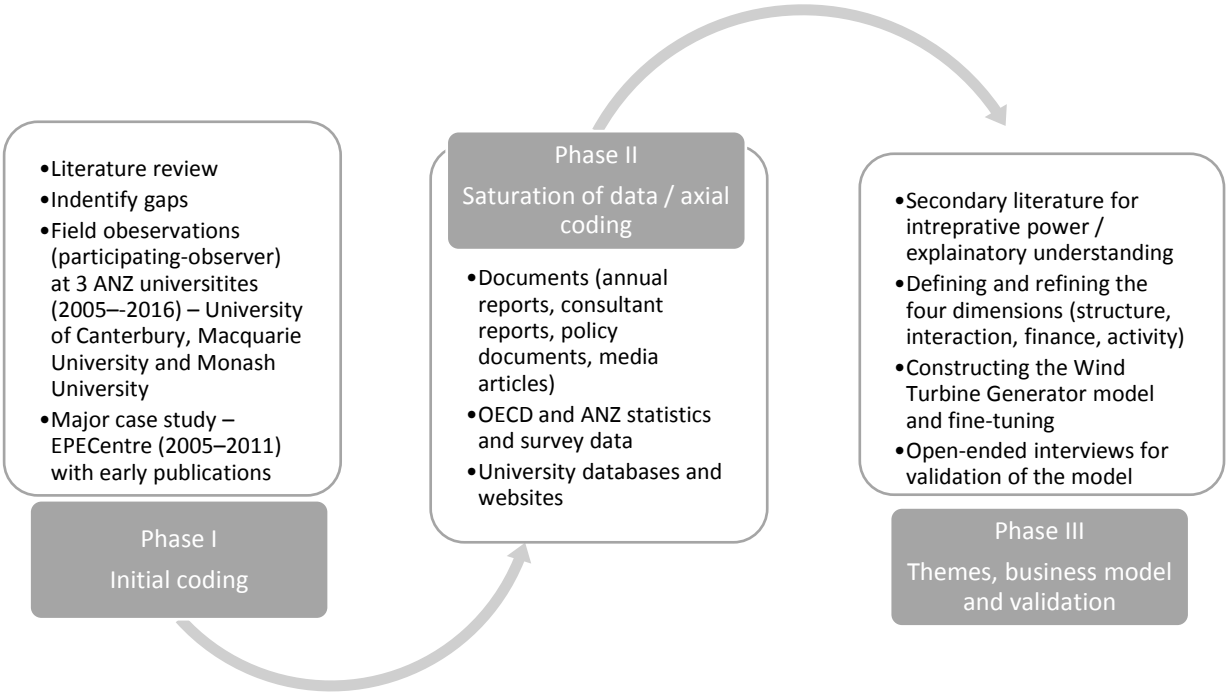


Figure 29 The qualitatively driven approach in a linear representation, qualitatively led with modified Grounded Theory from Phases I to III, ending with the themes for the business model (Appendix C), defined using dimensions and the constructed model, which has been validated by the interviews (Appendix B).

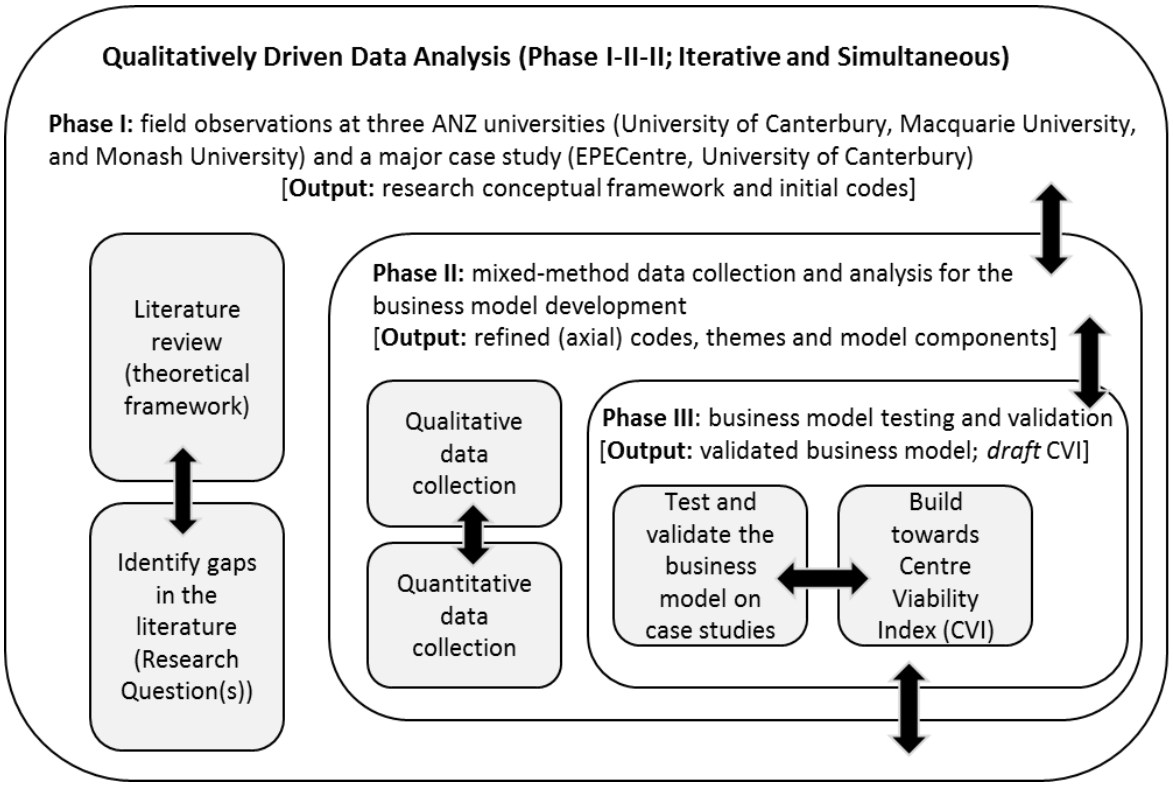


Figure 30 The research method (multidimensional, qualitatively led), which included the early development of an index that was outside the scope of this project (the development of a model), but indicated as an extension of work that was undertaken (Appendix D).

3.3 RESEARCH METHOD

Further to the research methodology being understood, the next step in the research design was to address the research method, which includes how the data was generated or sourced, what tools or instruments were used to simultaneously collect data, and how the data was analysed in multiple iterations as the conceptual framework (Figure 28) was refined to address the key research question.

A significant foundation for the research method is the contextual boundaries of the research. In this case, the topic itself is specific to ANZ. Hence, this is the first layer of context. Second, the setting is universities in ANZ. Therefore, the study focuses on universities in ANZ and includes a mix of fieldwork observations, document analysis, published literature (books, journals, magazines and conference proceedings), public reports, public presentations, online content, media articles, surveys, interviews and case study analysis undertaken across multiple universities.

A major component of the research was fieldwork observations and testing of findings at three specific ANZ universities over 2005–2016: the University of Canterbury in NZ, including a major case study of the EPECentre; Macquarie University in Australia; and Monash University, also in Australia. The fieldwork included testing and validation of the research findings and components of the model on over 20 IA collaborative initiatives, including 12 research centres. The logic of this approach, which draws on elements of comparative case studies, institutional documents and observable field notes, paints a comprehensive picture of IA collaborative centres within ANZ universities from multiple dimensions, which in turn enriches the scope and generalisability of the research findings, grounded on empirical evidence.

This has been enhanced by the researcher being a participant-observer conducting insider-led research. Being an insider conducting research has many benefits and some disadvantages, but the benefits significantly outweigh the negatives, according to scholars (Unluer, 2012; Dover, 2008). “Participatory methods are most effective when the researcher has built strong relationships and trust and this can often take many years” (Dover, 2008, p. para 1). This is a condition that has been met by the researcher, having been an employee of each of the field-site ANZ universities, in roles that span the university environment from department to faculty and to central university. This is addition to managing and directing an IA S&T centre, as well as being responsible for IA collaboration across a university, with appropriate written permissions where required. Thus, the relationship and trust aspect was in place to conduct the research from 2005–2016, including some periods of non-research.

Context is a theoretical concept and how it is viewed is dependent on the researcher’s theoretical orientation (Mason 2006). For this project, the researcher’s contextual perspective is from within ANZ universities. This is demonstrated by the way the elements of the research conceptual framework have been mapped by the researcher, essentially a storyboard in filmmaker terminology (Miles, et al., 2014).

Furthermore, the research has extended to generating and collecting qualitative and quantitative data pertaining to the topic of IA collaboration and then narrowing down to case studies of centres. In parallel, the research has looked at the macro ANZ environment for economic activity involving industry, government and universities linking to the topic area. This relates to policies, statistics and documents that provide evidence of the macro dimensions at play that must also be taken into consideration (i.e. the multidimensional logic of the research methodology) in order to answer the key research question pertaining to the recommended business model for IA S&T centres in ANZ universities.

The data collection process for the mixed-method approach in relation to the research instruments (Miles, et al., 2014) used to collect the data is summarised in Table 7.

Table 7 The data collection process for the project using qualitatively driven mixed methods.

Data type: Qualitative (QUAL) or Quantitative (QUAN)	Data Instrument / tool	Description
QUAL	Field-note observations from three ANZ universities	Field notes from the University of Canterbury, Christchurch, New Zealand; Macquarie University, New South Wales, and Monash University, Victoria, Australia; including university, industry and government perspectives and experiences pertaining to IA collaboration and centres.
QUAL	Case studies	Centres across Australia and New Zealand: including major case study on the EPECentre, University of Canterbury, Christchurch, New Zealand; plus other IA centres across ANZ, plus some comparative centres internationally.
QUAL	Literature	Books, journal papers, conference papers, magazines.
QUAL	Artefacts	Strategic plans from universities, published reports on topics pertaining to IA collaboration, annual reports, policy documents, centre capability brochures, presentation slides from conferences and seminars.
QUAL	Media articles	Press releases and news articles.
QUAL	Online material	Websites for centres, online posts and blogs.
QUAL	Interviews	Open-ended interviews on the topic.
QUAN	Statistics	Australia and New Zealand statistics pertaining to IA collaboration, knowledge transfer, economic indicators such as OECD statistics.
QUAN	Surveys	University, industry and government surveys for opinions and statistics on demographics.

Overall, the results have been produced using mixed-method qualitative and quantitative approaches, which include field observations by the researcher as a participant-observer conducting insider-led research in the university context at three university field-sites in ANZ. The universities are the University of Canterbury in Christchurch (New Zealand), Macquarie University in New South Wales (Australia) and Monash University in Victoria (Australia), respectively over 2005–2016.

The research also includes a major in-depth longitudinal case study of an S&T centre, which was also used as a testbed for concepts explored throughout this research over 2005–2011. This centre is the EPECentre at the University of Canterbury. A number of academic papers have been published by the researcher on the case study over that period.

In addition to conducting rigorous field testing of key concepts and ideas over the course of the participant observations (i.e. 12 centres between 2005 and 2016), the research has been qualitatively led with modified Grounded Theory, where, instead of beginning with interviews for the coding process, it was initiated with the EPECentre case study and participant observations (Appendix C). The research has been completed with validation interviews in early 2016 (Appendix B) with senior representatives from the university sector, government and industry, in order to minimise researcher bias, and test the feasibility of the key findings and the acceptance of the business model for ANZ universities.

The next chapter presents and discusses the results (Chapter 4).

CHAPTER 4. RESULTS AND DISCUSSION

The purpose of this research study is to explore and understand business models suited for industry–academia collaborative S&T centres within ANZ universities. The study endeavours to determine the key components required for the implementation of such centres and especially to understand what it takes to make them viable beyond the initial establishment phase, so that these centres can be sustained to generate ongoing benefits for ANZ.

The results have been generated using mixed-method qualitative research (Chapter 3), which includes the researcher as a participant-observer conducting insider-led research from the university context at three university field-sites in ANZ (University of Canterbury, Macquarie University and Monash University). This also includes a longitudinal case study of an IA S&T centre, the EPECentre at the University of Canterbury, from 2005–2011.

The observations at the three ANZ universities and the major case study have been analysed (using modified Grounded Theory; Chapter 3) and supplemented with policy documents, university documents, industry reports, government reports, media articles and websites. Furthermore, statistical data from the Organisation for Economic Co-operation and Development (OECD) and survey data from the Australian Institute of Management (AIM) and the NZ Institute of Management (NZIM) is included in the ANZ background for the study (section 1.2). Lastly, open-ended interviews were conducted in Melbourne, Australia over the early part of 2016 with a selection of participants from university, industry and government (Appendix B) to validate the findings for the recommended model (Chapter 5), and to minimise researcher bias, the researcher being a participant-observer conducting insider-led research.

THE KEY RESEARCH QUESTION:

- What is the recommended business model for industry–academia collaborative science and technology (S&T) centres within ANZ universities?

  Sub-questions:

  - *What are the types of industry–academia S&T centres within universities in ANZ?*
  - *How many industry–academia S&T centres are operational in ANZ universities?*
  - *Why are industry–academia S&T centres within universities important to ANZ?*

The key research question and the sub-questions have guided data collection, which has resulted in the central themes that emerged through the coding process via the application of modified Grounded Theory (Appendix C). This chapter outlines and discusses the key findings for each central theme. The conceptual research framework, which links existing theory to relevant ANZ background in order to address the key research question, is depicted in a mind map (Figure 31).

The emerging central themes from the modified Grounded Theory analysis are listed in Table 8, which feeds into the thematic segmentation of the results and discussion that follows.

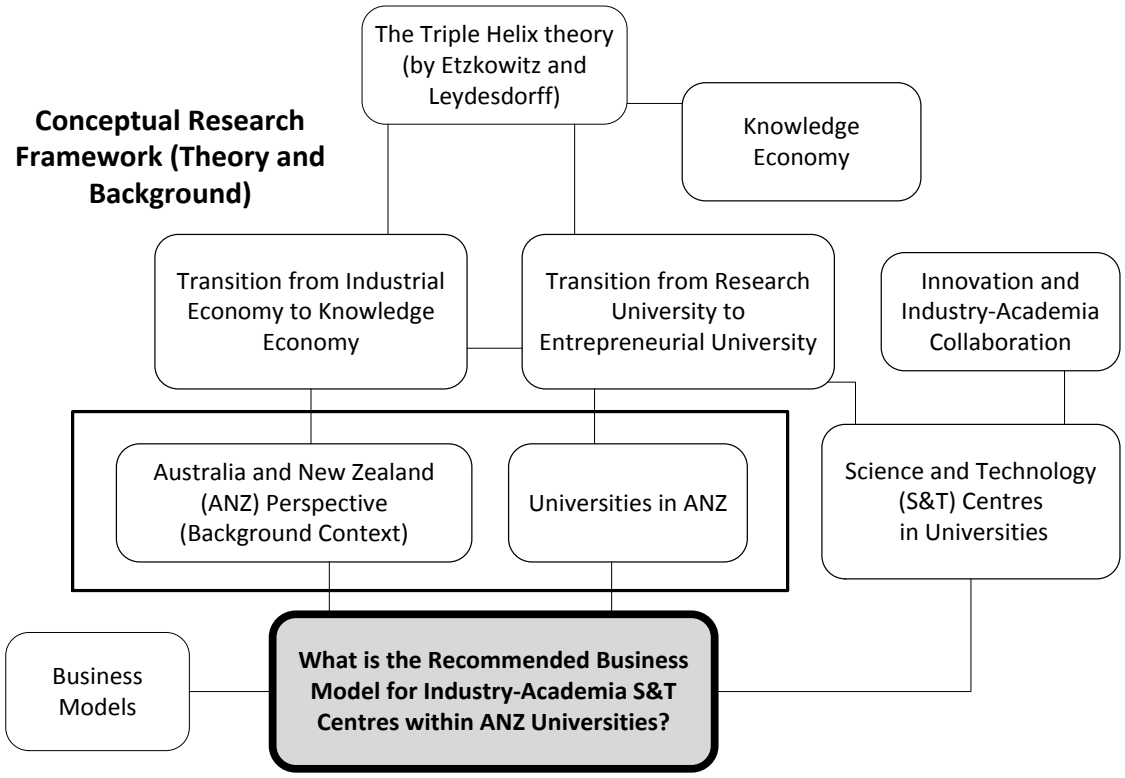


Figure 31. Mind map of the conceptual theoretical framework and background as it links to the key research question.

Table 8. The emerging central themes of the research study post-modified Grounded Theory analysis (Appendix C).

Themes:
▪ The ANZ operating environment
▪ University hosting arrangements
▪ The underpinning academic capability
▪ Government support
▪ Strategic leadership
▪ Governance
▪ The team
▪ Industry partners
▪ Portfolio of activities for impact

4.1 THE ANZ UNIVERSITY LANDSCAPE

The ANZ university landscape has been studied across three field-site universities over 2005–2016. The sections that follow outline the results from the observations of the ANZ university landscape, such as demographics, academic staff engagement with industry and university–industry collaboration activity.

4.1.1 ANZ UNIVERSITY DEMOGRAPHICS

There was found to be a total of 50 universities in ANZ as at 2016 (Universities Australia, 2016; Universities New Zealand - Te Pōkai Tara, 2016). In order to provide context for findings across the three ANZ universities, Table 9 provides a key synopsis of ANZ university demographics, while

Appendix A contains a more detailed summary of the key quantitative data that has been collected over 2005–2016 and analysed for this research study.

Table 9 Key ANZ university demographics and implications for the research study (Appendix A for full summary).

Key demographic factors found:	Implications for IA centres in this study:
a) 50 research universities in ANZ (42 in Australia and 8 in NZ) in the transition to entrepreneurial universities, of which 94% (47) are public universities.	All universities in ANZ are research-intensive universities with active research centres.
b) The average age of ANZ universities was calculated to be approximately 84 years.	Mature universities, thus indicating a level of stability to sustain IA collaborative centres.
c) The average size of ANZ universities is deemed large when greater than 30,000 students (Quacquarelli Symonds World University Rankings, 2016) and has been estimated to have 40,189 students per ANZ university.	The large size of ANZ universities imply scale and capability to engage with industry on both education and research.
d) Across the field-site universities, there is a range of 14,725 (medium), 38,747 (large) and 67,067 (extra-large), respectively, for the University of Canterbury, Macquarie University and Monash University; noting that Monash University is the largest university in ANZ (Quacquarelli Symonds World University Rankings, 2015b).	The field-site universities represent a sampling of one medium, one large and one extra-large university. Hence, the observations at these field-sites provide a balanced view that is sufficiently general and therefore applicable to all ANZ universities.
e) The average number of staff per ANZ University is estimated to be 1577 academic staff and 2600 non-academic staff.	Research is undertaken by the academic staff and the non-academic staff perform support or management functions.
f) The ratio of business development and commercialisation staff to academic staff is calculated to be 1:173 for an ANZ university.	This shows a heavy demand on existing business development (BD)/commercialisation staff. Hence, IA centres will likely need dedicated BD-type resources for successful IA collaboration.
g) On average, there are 43 departments and 6 faculties at each ANZ university.	There is significant multidisciplinary capability at each ANZ university, with breadth and depth to support IA centres and add value to industry.
h) There are an estimated 5850 centres in ANZ universities, with an average of 117 centres per university, compared with over 37,000 centres, including non-university based, estimated internationally (Boardman & Gray, 2010).	This 5850 represents at least 15.8% of research centre population globally. However, this includes centres in all areas of academic endeavour, such as humanities, arts, medicine and health sciences, while the focus for this study is on science and technology. All these centres may benefit from a sound, well-researched business model.
i) 1600 (27%) of the 5850 centres in ANZ universities are estimated to be S&T centres, based on Monash University's distribution of centres; given its extra-large size, it is representative of all the various types of centres possible in ANZ, although it was not possible to ascertain how many of these were specifically IA centres from the database analysis.	This is a key target audience for the recommended business model for S&T centres within ANZ universities, of which there are approximately 1600 centres.
j) Approximately 102 of the 1600 centres are part of an official government-funded program specifically for S&T centres, such as via the Australian Research Council (ARC) in Australia (Australian Research Council, 2016) and the Tertiary Education Commission (TEC) in NZ (Tertiary Education Commission, 2016). Hence, 1498 S&T centres are independent.	The 1498 represents 93% of all S&T centres in ANZ universities, which do not have a common framework or guidelines, such as those of the ARC or TEC. Hence, these centres could benefit from a recommended business model. The 1498 also includes a number of one-off IAG centres, operating without a common framework or business model per se.

The key statistic from Table 9 is the number of S&T centres within ANZ universities: 1600 out of an estimated total of 5850 centres within ANZ universities. These two groups represent the target market for the recommended business model.

4.1.2 ACADEMIC STAFF ENGAGEMENT WITH INDUSTRY

Misconceptions have been observed when it came to perceptions of industry activity by university staff and vice versa. For example, during a field observation, a senior academic in ANZ was heard saying, "Publishing in top journals is what gives science impact, but I suppose industry can have impact too". Moreover, working with industry was generally perceived by the traditional academic community to be less prestigious than basic discovery research, but many academics showed interest in collaborating with industry nevertheless.

These findings at the field-site universities seem to resonate with a study of academic staff constraints for engaging with industry conducted in the UK. This found that 40% of academics had engaged with industry at some point and that the largest constraint for working with industry was the lack of time available (Abreu, et al., 2009). Furthermore, the report states that academics perceived research and publication to be the most important outputs for career advancement, followed closely by administrative duties, teaching ability, industry engagement and community engagement (Abreu, et al., 2009), thus indicating that industry engagement is relatively further down the priority chain for UK academics.

Goals for industry collaboration were strongly emphasised within university strategic plans as vehicles for cultural change. This was observed at all three field-sites.

Also of interest are the cultural slogans used within field-site universities: "People prepared to make a difference" (University of Canterbury, 2015); "Engaging with the world" (Macquarie University, 2015); and "Enterprising Monash" (Monash University, 2015). These statements about making an impact provide an indication of a transition in progress at each of the field-site universities along the lines of social and economic impact. This is the transition from research universities to entrepreneurial universities in the KE in line with the Triple Helix theory by Etzkowitz et al. and other scholars (sections 2.1 and 2.3).

4.1.3 UNIVERSITY AND INDUSTRY COLLABORATION ACTIVITY

Pasteur's Quadrant (subsection 2.11.5) states that there are three different types of research: basic research, use-inspired basic research, and applied research. However, this study has found that S&T centres in ANZ universities, with an end-user engagement consortium, utilised consulting and commercial development as a lead into applied research and use-inspired basic research, as well as basic research:

- Applied research for the EPECentre's power quality in electricity distribution networks research program in 2008–2011, which stemmed from consulting projects with EPECentre members Orion NZ and Transpower NZ over 2005–2006[14]
- Use-inspired basic research on power transformers, with scholarships for PhD students provided by the EPECentre,[15] which stemmed from consulting projects and commercial development projects with IP produced by EPECentre's academic research associates at the University of Canterbury; this included a large-scale commercial collaboration with EPECentre member Meridian Energy in 2003.[16]

[14] Source: http://www.comsdev.canterbury.ac.nz/canterbury/Canterbury0802.pdf

[15] Source: http://nzresearch.org.nz/records?i[creator][]=Bodger%2C+P.S.&i[creator][]=Bell%2C+S.C.&i[display_collection]=UC+Research+Repository&locale=en&recordset=research

[16] Source: http://www.comsdev.canterbury.ac.nz/news/2003/03070402.shtml

- Work on power transformers translated into a parallel stream of basic research that examined the fundamentals of lightning, with a number of postgraduate projects and leading international journal publications, such as IEEE Transactions on Plasma Science by Sinton et al. (2010).

This evidence from the EPECentre case study suggests that there is an observable link between consulting (C), applied research (R_A) and use-inspired basic research (R_{UI}), and that this indirectly inspires basic research (R_B):

i.e. $C \rightarrow R_A \rightarrow R_{UI} \dashrightarrow R_B$

Evidence also suggests that this may not be a linear process in one direction, but an omnidirectional phenomenon. This would require further testing, as the findings here are based on a single IA centre. Nevertheless, the field-site observations indicate that there was generally a lower priority on consulting activity with industry when compared to research and teaching activity. For example, during one interview an academic staff member commented on an S&T centre that was thought to be too consulting-orientated that this centre did not "stretch into the real crux of academia around research and research training" and hence the academic did not see it as core university business.

Moreover, the literature also implies that consulting is not encouraged by the broad academic community involved with IA centres, who appear to regard it as a deviation from publishable research activity. The emphasis seems to be on use-inspired research, while some suggest balance and others see it as an avenue for income to pay for host university overheads (subsection 2.10.1). Nevertheless, the likes of Dooley and Kirk, Arnold et al. align with the finding that this is a sensible approach and adds value to industry, provided it is resourced and managed properly (subsection 2.9.4). The EPECentre finding aligns with the preceding view that professionally managed consulting is sensible as a key source of revenue and value-adding to industry participants and academics.

At a fundamental level, the very definition of research excludes consulting because it is applying known knowledge, as opposed to generating new knowledge. However, it can be argued that the very application of knowledge through consulting leads to tacit knowledge creation (section 2.1) and application experience that can be utilised in unexpected ways to lead to new knowledge. In fact, the term 'R&D' in practice across the field-site universities encompassed consulting, despite the fact that the term 'research' did not.

There is a rationale here to suggest a reorientation of IA research centres in universities towards repositioning themselves as IA R&D centres, which is likely to enhance IA collaboration opportunities and align with the needs of ANZ, given the large SME population and poor OECD performance for industry and university collaboration, and for research translation into commercial value (section 1.2; ANZ Background). This is indeed an area worthy of further investigation and concurs with the very description of an entrepreneurial university by (Etzkowitz, 2008) (section 2.3).

Recognition of Industry Collaboration

Universities typically run annual awards ceremonies that recognise individual teaching and research excellence, but exclude awards specifically for industry collaboration. However, some universities appear to have moved towards this, such as Monash University, which includes an annual Vice Chancellor's Award for Research Impact (Economic and Social),[17] which is aligned with the entrepreneurial university and KE concepts.

Industry Relationship Management

It has also been observed that universities typically had difficulty in managing databases of industry engagement activity. Many adopted customer relationship management (CRM) software tools, such

[17] Source: http://monash.edu/news/show/2015-vice-chancellors-education-and-research-awards

as Salesforce[18], which were found to be difficult to manage within a university. This is given that engagement with industry happened at so many different levels, often involving the same company being approached independently by different faculties, departments, centres and central offices, e.g. the technology transfer office (TTO). Therefore, it has been found that some centres, such as the EPECentre, resorted to implementing and managing their own simple and independent CRMs.

All the field-site universities had business development managers and technology commercialisation managers. These roles, underpinned by university strategy set by the vice chancellors, were to support industry engagement and technology transfer. Hence, the support offered included proposal development, project costing according to university financial policies, providing commercial advice to academics (e.g. project negotiations with industry or government), relationship building with industry and input into contractual agreements for research and consulting. KPIs applied to these groups included the number of patents generated by the university, number of licence agreements with industry, invention disclosures by academics, number of grants with industry and total value of income generated via industry engagement for the university. Therefore, given their KPIs, this group is incentivised to provide significant support for IA activities, even though they are under-resourced (1:173 academics, Table 9). Many centres utilised this capability and it is one of the many benefits of hosting an IA centre within a university, and a strength not highlighted in the literature.

4.2 UNIVERSITY HOSTING ARRANGEMENTS

Hosting arrangements within a university for an IA centre are of critical importance. It is indeed the foundational footing to support a centre, and can either undermine the whole centre operation or add significant stability for it to thrive.

4.2.1 HOSTING ARRANGEMENTS FOR A CENTRE

This study has observed that S&T centres typically rely on shared resources within a university, especially business development and technology commercialisation managers, to support their centres for industry engagement and technology transfer. Centres also accessed departments or faculties for administrative support and sought service support from host universities' solicitors, finance, human resources, IT and marketing and communications, as well as the research office for research development advice.

A host university was also expected provide in-kind support through academics' time allocation to the centre. In addition, S&T centres relied on infrastructure (laboratories and equipment) to perform research and consulting. For example the EPECentre had a dedicated shopfront within close proximity to key laboratories and equipment, with technical support on hand from the host department's technical staff, who were also regarded as EPECentre research associates.

This highlights the importance of hosting arrangements for a centre within a university, including the need for geographic proximity, administrative support, service support and an operating space. This is because a centre needs access to specialist R&D laboratories and equipment for industry projects, visibility to be effective in industry engagement (i.e. a shopfront), as well as back-office support for items such as invoices, contracts and purchases.

This support from the host university, including the discounting of overheads, specialist staff time, use of infrastructure and academic participant time, are expected during the formation of centres and referred to as in-kind support. Moreover, government grants for centres stipulate in-kind support as a requirement and independently audit host universities to ensure that the in-kind support is actually provided to a centre as per the proposal e.g. the ARC ITRH and ITTC programs (Australian Research Council (ARC), 2015, p. 8). This is not something that is highlighted in the

[18] Source: https://www.salesforce.com/au/?ir=1

literature, other than in relation to the role strain effect and the conflicting demands on academic participation in centres (subsection 2.9.3). The in-kind support for a centre can equate to significant value-adding for a centre, in terms of reductions in operating costs, through support provided by the host university.

4.2.2 MARKETING AND COMMUNICATIONS

Communications and marketing units within the universities were normally focused on promoting education, student enrolments and research achievements, e.g. major research grant awards or breakthroughs. The publicising of industry–university activity and activities within centres appeared to be a less of a priority. In fact, one professor during an interview for this research study stated that "Many centres don't have a brand or PR presence and that's not good!"

Branding, e.g. centre name, logo, shopfront, website and business cards, can be a point of contention between a centre's unique identity and the brand image of the host university. Naturally a centre wants to be differentiated in order to get recognised by industry and academia; however, the university wants conformity. Centres should aim to work closely with the host university marketing team, rather than rebelling against the university's branding. For example, the EPECentre had its own established brand identity separate to the university, which is unlikely to be changed given its brand recognition by industry. Contrastingly, in the C&P Innovation Program at Monash University, the centre staff worked with the university to develop an agreed brand for the centre within the protocols of the university.

Ultimately, marketing and communication issues must be addressed upfront during the formation of a centre, as part of hosting arrangements, rather than risking future impediments as a centre tries to make a name for itself within the often strict boundaries of the university branding system. Youtie et al. (2006) and Boardman and Corley (2008) concur: it is essential that a centre has a profile within the university and outside the university. However, it is important to note that the internal and external images of a centre are aimed at two very different market segments, i.e. academics and students versus industry and government. Hence, a one-size-fits-all approach to marketing and communications will be ineffective – an important distinction that is not discussed in the literature.

4.2.3 BUSINESS PROCESSES FOR INDUSTRY ACTIVITY

University overheads and co-investment: Ongoing effort was observed across all three examined ANZ universities to streamline and improve business processes associated with industry activity and external engagement. University overheads and space charges appeared to be a recurring point of confusion and frustration for industry-related activity, especially when non-standard strategic co-investment approaches were involved in the establishment of centres.

However, it is feasible to offset overheads and space charges as a part of the co-investment strategy in a centre. What this highlights is the need for ANZ universities to take greater steps to educate academics, managers and administrators on strategic co-investment paradigms. It means that universities could indeed be more entrepreneurial by leveraging their assets through measures such as offsetting overheads and space charges, recognising government block grant incentives for IA research funding (e.g. Category 3 funding in Australia; subsection 4.3.2), providing in-kind support and underwriting centre staff salaries, which have all been observed as tactics within the ANZ universities, ultimately to allow centres to have a more stable footing. However, it is best to engage with appropriate managers within the university to work through such issues, so as to avoid conflict.

Intellectual property and the publishing conundrum: Misunderstandings about IP were another cause of confusion for centre participants, especially when trying to separate background IP from new project IP. This was exacerbated by limitations in understanding licencing technology, the difference between royalty fees versus licence fees, and also the pros and cons of having IP assigned.

Restrictions on publishing with respect to industry projects can cause anxiety for inexperienced participants in the university and, to a lesser extent, industry. Many projects resorted to having industry review prior to publishing to ensure that commercial sensitivity was managed. This is particularly a concern for PhD projects; for example, the C&P Innovation Program at Monash University has an inaugural cohort of 17 PhD students with over 20 industry partners. Each PhD project with industry has to be carefully managed for commercial sensitivity. To counter this, the C&P Innovation Program moved to establishing a default intellectual property rights (IPR) position on all its industry PhD projects which allows for one-to-one negotiation with the few industry partners that want IPR adjustments. The default IPR position is one where the university owns the IP but the industry partner has the right to licence the IP for free in return for a negotiable royalty payment if the IP generates gross revenue for the industry partner. This approach not only achieves commercialisation aims for the company, but also drives an incentive for researchers to aim towards commercially viable IP.

The IP challenge requires greater education and support for both university and industry participants in IA centres. It is a known issue (subsection 2.10.2). However, the approach taken by the C&P Innovation Program is novel and progressive. Time and energy are apportioned to resolving IPR issues with only the participants that have concerns, rather than with all participants. Furthermore, participants know where they stand on IPR from the outset, rather than enduring misunderstandings later. The host university also provides support for IP protection as a part of its in-kind co-contribution, which is advantageous to the industry participants, especially SMEs in ANZ who do not have access to such a resource. Etzkowitz and Kemelgor attest that "there is little need for a formal technology-transfer office when company and university researchers can interact freely at a centre" (Etzkowitz & Kemelgor, 1998, p. 284), but this rhetoric is not supported by the findings of this research study.

Budgets and costing versus recruitments and purchases: Issues were noted to arise when external funding grants were awarded but the projects had not been costed (budgeted) properly according to university policies (e.g. overheads and space charges), and new staff recruitments or equipment purchases needed to be made. The balancing between budgeting, recruitment and project-related purchases has not been addressed in the literature, although Garrett-Jones and Turpin note that participants in different organisations use different costing models (Garrett-Jones & Turpin, 2007), and that budgets are limited and need to be managed by centre management (subsection 2.7.3 and 2.9.2).

Perhaps this is because the literature reflects the opinions and viewpoints of scholars who are observers, rather than those dealing with the deeper operational issues of a centre. For those who do have experience, it may not be a topic that is comfortably discussed, given that it illuminates mistakes and errors of judgement. Nevertheless, as a practical solution for centres, host universities have business development and research development managers (section 4) who could be called on to provide advice to cross-check and fix such issues upfront, so as to avoid such occurrences.

Policy and reporting: Reporting on expenditure, commercial sensitivity and policy limitations issues also occurred. Table 10 provides a summary of the types of confusion caused by financial systems and policies with respect to centres, based on the EPECentre case study and the field-site ANZ universities. However, many issues have been found to be mitigated through professional management approaches, starting with greater training for centre management on host university processes.

Table 10 Summary of the types of confusion caused by university systems.

Types of confusion caused by systems and processes:	Implications for IA centres in this study:
a) Typically a research project is fully managed by the chief investigator (lead researcher). This means juggling multiple projects, each with its own research scope, cost, time and resource issues, and keeping on top of milestones, contract obligations and IP considerations, monitoring account balances, stakeholder reporting and invoicing. This is unless they have their own project manager (usually a postdoc working on the project). Several academics were observed to miss deadlines and faced contractual repercussions with government and industry. However, some centres such as the EPECentre provided this project management support so that busy researchers with multiple projects could concentrate on the research.	This is flagged as role strain in the literature by Boardman and Ponomariov (subsection 2.9.3). Also, funding agencies such as the ARC and the NSF in the USA allow for a centre manager to support a centre director (subsection 2.10.1). However, the lack of executive management training and program or project management experience for centre directors and managers (e.g. a freshly minted postdoc) is a significant issue that could impact on centre performance. Hence, such training should be offered as part of the host university's responsibility.
b) Calendar year (January–December) reporting in universities versus financial year (July–June) reporting in industry.	This is a minor issue but an important one, as centres could easily be confused on dates, e.g. reporting on milestones. However, the deployment of professional project management approaches could easily mitigate this issue.
c) University budgets are assigned at the start of the year and reset to zero at the end of the calendar year, unless a carry-forward arrangement is set up, so 'use it or lose it' is a common phrase among researchers. However, industry finds this very confusing.	In fact, none of these issues from b) to h) *(listed on the left hand column)* are flagged in the literature. However, these niche issues do need to be addressed and mitigated for a centre to achieve stability within the host university operating environment. For example, d) an IA centre would prefer to have a project accounting level view, while university finance prefers to have an overall activity based view. This can cause confusion when centres attempt to report on project activities to industry stakeholders and advisory boards. In the case of e) there is a need to optimise the time taken for the processing of contracts with industry. The findings at Monash University suggest that centres ought to adopt bespoke contract templates at the outset to avoid repetition and delays in the legal process. For f), many centres feel that university overheads are excessive, while from the point of view of finance it is essential to cover the true cost of doing project activity. Business and research development management roles were observed to be heavily involved in project budgeting processes and providing proposal development support for most researchers. Therefore, it is advisable for centres to establish dedicated management resources to abiding by host university requirements in order to achieve stability.
d) Financial reporting within some universities itemise expenditure by type of activity (e.g. travel) rather than by project (e.g. by a project's name), which leads to confusion when reporting to industry on specific project expenditure.	
e) The processing of agreements and invoices can take time in a university. Many staff shared their frustration with systems and processes and felt that it may be hampering industry engagement. One solution Monash University has introduced is a multi-year collaboration agreement where one-page schedules can be added on demand over a period of time, while an overarching head agreement stays in place for the entire duration of the collaboration with a specific industry partner.	
f) Costing tools within universities for external research projects can generally be misunderstood by university staff and industry alike, e.g. terminology such as on-costs, overheads, space charges and contribution margins.	
g) The financial systems generally view block grant funding from government that results from a project as independent of a project.	
h) Researchers, project managers and centre directors and managers do not have real-time access to view account balances and rely on department or faculty finance administration staff to provide monthly updates or by special request.	

In the EPECentre case study, it has been found that the core budget (funded by an industry membership consortium via a charitable trust) consisted of program funding, operational expenditure, manager salary, travel and administrative costs. As a policy, the University of Canterbury ensured that trust funding for the EPECentre was not exposed to overhead charges.

However, research or commercial income generated by the EPECentre was generally expected to cover the full cost of overheads, according to university financial policies, unless an alternative arrangement was negotiated. Furthermore, having a supportive head of department and pro vice chancellor, and an industry advisory board (IAB) was observed to be a crucial element in the hosting arrangements for the EPECentre. To this end, the EPECentre adopted a Memorandum of Understanding (MoU) to define its hosting arrangements within the department, countersigned by the IAB and the pro vice chancellor of the faculty. The MoU was further endorsed by the head of department and the centre director. An MoU is non-binding but was the only viable approach, given that both entities themselves are part of the host university, i.e. not separate legal entities. Hence, an MoU serves the intended purpose of setting expectations between a centre and a host department.

This approach used by the EPECentre is recommended as an excellent approach in centre establishment within the complex environment of universities. Although an MoU is not legally binding, IA and IAG centres which are university led and hosted are not legal entities; rather, they are quasi-departments within the university organisation. Therefore, an MoU signed by the centre director and head of department and countersigned by the IAB and a university executive up the chain of command, such as a pro vice chancellor, dean or provost, sets mutual expectations and achieves understanding across the managerial chain. It serves as a modus operandi for the centre within the university environment for addressing issues such as space charges, overheads and any amendments to standard university protocols.

Furthermore, an MoU can be used to mitigate risks of changes to key personnel that happen in the lifetime of a centre. In fact, the longitudinal EPECentre study from 2005–2011 shows that a centre can experience up to three changes in heads of departments and several changes in IAB and centre directors within a decade. Therefore, a key new finding is for any centre to adopt the practice of an MoU with the host department or faculty. This would apply to any form of centre, e.g. the 5850 centres in ANZ universities (Table 9) could benefit from such an approach, and perhaps for adoption by international universities also.

Lastly, the lack of recognition by a university for team effort on a successful funding grant (e.g. developed by a team of people associated with a centre) can cause negativity among a team within a centre, especially when a single person is recognised or congratulated with no mention of the team. This is flagged by the likes of Etzkowitz and Kemelgor (1998) and Stahler and Tash (Stahler & Tash, 1994) in the literature (subsection 2.7.1).

4.3 UNDERPINNING ACADEMIC CAPABILITY

Centres are underpinned by the academic research capability of the host university. This encompasses the multidisciplinary capability and the calibre of academics and their research performance, and associated university incentives and metrics for research excellence.

4.3.1 EXCELLENCE IN RESEARCH METRICS

The Excellence in Research for Australia (ERA) and Performance-Based Research Fund (PBRF) in NZ are based on the Research Assessment Exercise (RAE) used in the UK. These metrics impact heavily on universities in ANZ. There are dedicated teams of people managing the submission and data collection processes for these metrics within ANZ universities. Currently, industry activity per se is not directly gauged by these metrics. Efforts are underway by the likes of the Australian Academy of Technology and Engineering (ATSE) (Australian Academy of Technology and Engineering , 2016) to suggest such metrics:

- NZ PBRF metrics are individual based: A (world class), B (original or recognised), C (sound research base), and R (research inactive)[19]
- Australia ERA metrics are discipline based, i.e. fields of research (FoR): ERA 5 (well above world standard), ERA 4 (above world standard), ERA 3 (at world standard), ERA 2 (below world standard), and ERA 1 (well below world standard)[20]

Typically for the establishment of centres within an ANZ university, there is a natural quality control filter applied. This is gauged by national metrics for excellence, by considering PBRF in NZ and ERA in Australia as unstated rules by the selection criteria or committee approval processes to establish a centre within a university. These become a gauge for universities to underpin support, and also a report card of sorts for industry and government that wish to engage with the university to host a centre. Therefore, the better the academic underpinning capability of the host university, the better the research and education substance to support a centre. It is a measure of depth and breadth when multidisciplinary capability is sought in order to provide a mix of education, research and innovation, which are all crucial elements for an IA centre's value proposition to stakeholders, as discussed pertaining to a centre's portfolio of activities (section 4.9).

Such measures could also be utilised by centres to identify weaknesses in capability and seek either gap-fill countermeasures or partnering opportunities with other universities, where 'gap-fill' refers to the strategic hiring of academic staff to bring strength to weak areas. In fact, universities can go from weak to powerful quite rapidly through cluster hiring tactics, e.g. two or three new professors and their research teams. This was observed at both Macquarie University and Monash University in Australia.

Alternatively, a partnering approach with other universities allows for complementarity. This may not always be possible in niche areas of science or engineering, where the compatible partner may be geographically distant, in which case a centre may opt to collaborate with that university remotely, rather than have a formal partnering per se. This was in fact observed to be less complex, e.g. in relation to governance and budget sharing, than the formal partnered approach, because it placed one university as the clear host university, while the other operated as a research collaborator, local or international, on selected projects only. Again, these concepts are not explicitly raised in the literature on IA centres and, consequently, no solutions have previously been offered. Nevertheless, the likes of the ARC in Australia encourage, indeed stipulate, multi-university collaboration on centres (e.g. ARC ITRH program). However, as noted earlier there are over 1498 centres (Table 9) in ANZ universities that do not have frameworks, such as that of the ARC, to guide them on 'autopilot' for such matters.

4.3.2 RESEARCH INCENTIVES

In a similar way to NZ's PBRF, research block grants in Australia provide incentives and rewards to universities for generation of different forms of research income (i.e. Category 1, 2, 3 and 4) as described in Figure 32. However, the block grants received were found to be regarded as secondary funding gains (in practice) and typically do not come into direct consideration when developing projects with industry or for IA centres. Interestingly, in Ireland block grant funding is used to provide support funding to IAG centres that come off program funding from government, as noted by Arnold et al. (2012). However, this is a separate matter to incentives and KPIs on academic staff.

Furthermore, it is important to note that consulting income is not deemed research, so it is excluded from research block grant funding and most metrics associated with research excellence. As

[19] Source: https://www.educationcounts.govt.nz/indicators/main/quality-education-provider/2031
[20] Source: http://www.arc.gov.au/excellence-research-australia

discussed earlier (subsection 4.1.3), if the definition of research was replaced by R&D, then consulting would fit the description of R&D.

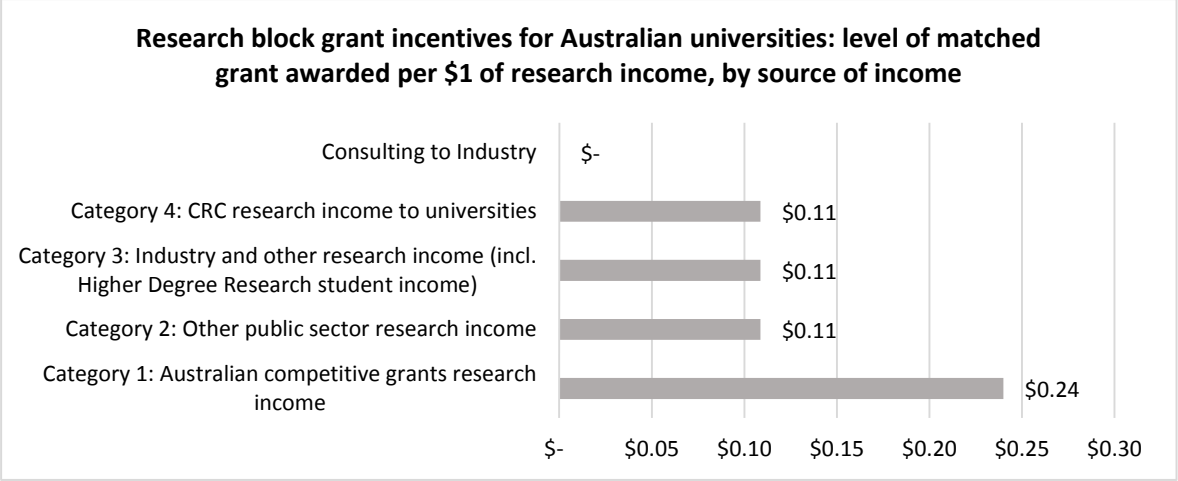


Figure 32. Research block grant varying incentive levels paid to Australian universities per $1 of research income, based on the source of research income (source: indicative rates used at Monash University as at 2016).[21]

At a more fundamental level, Figure 32 demonstrates that Category 1 (government grants) income is better than Category 3 (industry) research income, and certainly more important than consulting income. This message is echoed by university managers in finance, which in turn is heard by heads of departments, who ultimately set KPIs for academic staff, who may interpret this as Category 1 being the most important and ahead of all else, especially at the early career researcher stage and to achieve career progression. This is a burden not only on departments but also on centres, as academics have to choose between working with industry or focusing their time on Category 1 research grant proposals. Herein lies a contradiction between the signals from government stating that Australian universities should collaborate with industry and translate research into commercial use (section 1.2; ANZ Background), while on the other hand incentivising universities to focus on the opposite – securing funding that the government itself allocates in its own sectors of research interest. This is not in line with a transition to a KE, nor in the spirit of entrepreneurial universities (sections 2.1 and 2.3).

The current approach in NZ was difficult to gauge as block granting is integrated into the formula for the PBRF, while in Australia the distinction between block grant funding and the ERA is much clearer. Hence, policy amendments are recommended in Australia, and presumably NZ, pending further studies around this issue. Nevertheless, ANZ university leaders have the opportunity to demonstrate greater vigilance on this issue and take corrective measures, e.g. awards for IA collaboration (subsection 4.1.3), regardless of government policy.

4.3.3 UNIVERSITY WORLD RANKINGS

The world rankings performance of universities is a key consideration in the global perception of a university's core academic research and teaching capability. A number of ranking systems exist internationally that take into consideration research income metrics (including industry), student enrolment numbers and income, staff numbers and publication metrics, as well as global perceptions (including those of industry) via surveys. Two of the most globally recognised university ranking systems are the QS World University Rankings® and the Times Higher Education (THE). Rankings also

[21] Source: https://www.education.gov.au/research-block-grants-calculation-methodology

feed strongly into marketing a university to future students and to governments and industry for the purposes of research funding and partnering. Therefore, rankings are a key metric that universities measure against within a country and globally. Table 11 shows the performance of the three field-site ANZ universities for this research study (University of Canterbury, Macquarie University and Monash University) on the QS World University Rankings®.

Table 11 Field-site ANZ university comparisons on rankings (University of Canterbury, Macquarie University and Monash University).

QS World University Rankings® (as at 2016)[22]	University of Canterbury	Macquarie University	Monash University
World Ranking	211th	229th	67th
World Grouping	Top 250	Top 250	Top 100
Arts & Humanities	146th	76th	42nd
Engineering & Technology	161st	316th	39th
Life Sciences & Medicine	394th	335th	33th
Natural Sciences	211th	171st	54th
Social Science & Management	94th	103rd	30th
Ranking out of the 50 in ANZ	11th out of 50	13th out of 50	6th out of 50

Just like the ERA and PBRF and associated block grants, world rankings have a similar effect on external engagement with industry, government and potential research collaborators, locally and internationally. Therefore, there are implications for IA centres, with considerations for approaches such as cluster hiring in order to improve rankings over a longer period of time or partnering with other universities. The IA centres themselves are not motivated to drive up rankings, but host universities indeed benefit from the successes of IA centres in order to improve their rankings over a longer period of time, especially through a large distribution of high-performing centres.

Many of the ranking systems, such as the QS World University Rankings®, have a significant component of the rank attributed to international survey responses by industry personnel and other externals, so IA centres could have influence over time for the rankings of the host universities.

4.4 GOVERNMENT SUPPORT AND INFLUENCE ON CENTRES

Much of the scholarly literature focuses on centres associated with core government funded programs, i.e. industry, academia and government partnered centres (IAG; Figure 2), which can be visualised as having a temporary support scaffold around the centre, until the government funding term is completed. This is when IAG centres must either transition from IAG to IA and become financially sustainable without government core funding, or cease to exist.

[22] Source: (Quacquarelli Symonds World University Rankings, 2015b)

It is important to note that, beyond the core funding from dedicated government programs, there are other means of support for IA and IAG centres. Some of these funding opportunities can be directly accessed, while other support from government mechanisms is subtle and indirect, but could be leveraged by centres. This is discussed in the following sections.

4.4.1 GOVERNMENT SUPPORT FOR CENTRES IN ANZ

Government funding for S&T centres in ANZ universities range from the TEC-funded Centres of Research Excellence (CoREs) in NZ to the ARC Centres of Excellence (COEs), ARC ITRHs and ARC ITTCs. This is in addition to the other government strategically aligned 'one-off' centres that are associated with government priorities, e.g. the National Innovation & Science Agenda in Australia and the National Statement of Science Investment (2015–2020) in NZ.

In some cases, centres such as COEs and CoREs are distributed across several universities, i.e. multi-university centres, with one university as the lead; for example:

- The TEC CoRE MacDiarmid Institute operates across Victoria University of Wellington (lead), University of Canterbury, University of Otago and GNS Science, which is a Crown Research Institute (CRI); and
- In Australia, the ARC COE for Electromaterials Science (ACES) operates across six Australian universities, including the University of Wollongong (lead) and Monash University.

A point to emphasise is that university-led centres do not have legal status. Thus, a host university is responsible and accountable for a centre's actions, including the full underwritten risk and liability for the centre. Furthermore, the host university carries the professional indemnity and public liability insurance for the activities of a centre. This also means that centre directors must recognise that the host university has ultimate executive decision-making power over the centre, which has implications for the management and governance structure (subsections 4.5.1 and 4.6.1).

The TEC is the only NZ government agency for funding centres, the CoRE program, while currently no specific government program for IA centres exists in NZ. In Australia, the core funding for centres come from agencies in both the federal and state governments. Sometimes a mixture of co-funding from a group of government funding agencies is undertaken; for example, the Australian Synchrotron includes Australian universities, the State Government of Victoria, the ARC and a consortium of NZ Government, universities and CRIs.

Multi-university centres: Multi-university centres seem to be a rising global trend, e.g. NSF ERCs. In terms of benefits, a multi-university allows for broader depth of capability, while on the negative side, it can have complex governance process issues and potential conflict around project allocation, control and budget (subsection 4.3.1). However, by adding professional project management capability and structured processes for coordination, the negatives can be mitigated and positive outcomes achieved, e.g. ACES operates seamlessly and successfully across many ANZ universities. Therefore, the key finding here is that participants ought to be aware of this issue when forming multi-university centres and mitigate it at the outset. The other alternative, as outlined in subsection 4.3.1, is to collaborate with other universities on projects and activities, but not as co-hosts, e.g. the EPECentre had a number of other university collaborators that it called on for research projects on a needs basis.

Reporting: Often the progress reporting and KPIs placed on government-funded centres appeared to be obstructive and excessive, as indicated by participants across ANZ industry and universities. For example, it was found that some centres were required to write four detailed progress reports annually in addition to an annual report (which centre types?), while some programs imposed strict limitations on purchases and travel, e.g. the ARC (2015).

This demonstrates that government core funding imparts a level of rigidity for an IAG centre, in terms of operational restrictions on spending and administrative burden for reporting – analogous to a scaffold, that is both rigid and supportive at the same time. However, the benefits of receiving core government funding for a centre far outweigh the reporting burden, which was, to some extent, observed to be reduced via extra management resources; for example, the C&P Innovation Program's manager was responsible and accountable for keeping up with government contractual duties.

4.4.2 GOVERNMENT-FUNDED AND NON-GOVERNMENT-FUNDED CENTRES IN ANZ UNIVERSITIES

As a summary, Table 12 highlights current (2016) government funding for S&T centres in ANZ hosted or associated with universities. It shows the types of S&T centre based on the IA–Government (IAG) Code (from Figure 2), herein developed for the purpose of categorising centre types (subsection 2.10.1). The table also indicates whether a centre type is university led and university based, the funding period and funding level provided by the government if any, and the estimated number of such centres currently in ANZ.

Table 12 Sources of funding for different types of S&T centres in ANZ within universities (sources: (Australian Research Council (ARC), 2015; Tertiary Education Commission, 2016).

ANZ S&T centres at universities:	**Type of centre i.e. IAG Code?**	**University led and based?**	**Period of seed funding / co-funding and typical investment levels**	**Estimated number in ANZ (2015)**	**Part of target market segment (within the scope) for this research study? *IA or IAG and university led & based?***	**Examples of centres in ANZ**
ARC Centre of Excellence (COE)[23]	AG	Yes	Up to 7 years (up to AUD $35M total or $5M p.a.)	25	No *(not IA or IAG)*	ARC CoE for Electromaterials Science (ACES)
TEC NZ Centre of Research Excellence (CoRE)[24]	AG	Yes	7 years renewable (NZ $35M average[25])	10	No *(not IA or IAG)*	MacDiarmid Institute
CRC (Cooperative Research Centre)[26]	IAG	No *(many are co-located at universities)*	Up to 10 years, with no extensions; Funding levels vary for each CRC (2016 average of AUD $26M[27])	33	No *(independent and not university led)*	CRC for Water Sensitive Cities
ARC ITRH (Industry Transformatio	IAG	Yes	3–5 years (AUD $1.5M–$5M)	18	Yes	ARC ITRH for Australian Steel Manufacturing

[23] Source: http://www.arc.gov.au/sites/default/files/filedepot/Public/NCGP/CE17/CE17_Funding_Rules_new.pdf
[24] Source: http://www.tec.govt.nz/Funding/Fund-finder/CoREs/
[25] Calculated from source: https://www.educationcounts.govt.nz/__data/assets/pdf_file/0005/115853/CoREs-and-effect-Feb-2013.pdf
[26] Source: http://www.business.gov.au/grants-and-assistance/Collaboration/CRC/about-the-program/Documents/CRC-Programme-Guidelines.pdf
[27] Calculated from source: http://www.business.gov.au/grants-and-assistance/Collaboration/CRC/CRC-Programme-Review/Documents/crc-report-growth-through-innovation-and-collaboration.pdf

nal Research Hub)						
ARC ITTC (Industry Transformatio nal Training Centre)	IAG	Yes	4–5 years (AUD $2.1M–$5M)	16	Yes	ARC ITTC for Innovative Wine Production
Special centres (Government co-investment, and some with additional industry co-investment)	IAG, IG	some	Typically 3–5 years *(variable investment)*	1498 *(Table 9)*	Some *(typically these are formed around key infrastructure or government policy directives; not all are a part of a university, but some may still be hosted at a university)*	Melbourne Centre for Nanofabrication (MCN); Food Innovation Centre (FIC) at Monash University; C&P Innovation Program
Externally partnered customised centres, without government co-investment)	IA	some	Typically 3 years or more *(variable investment)*		Yes (*these in Australia may also look to leverage future ARC ITRHs or ARC ITTCs to expand core funding)*	EPECentre; Axieo Centre for Innovation; Bioresourcing Processing Research Institute of Australia (BioPRIA); Australian Power Quality & Reliability Centre (APQRC); DOW Centre for Sustainable Engineering innovation
Internal university centres *(customised)*	A	No	Typically 3–5 years *(variable investment by the university)*		No *(discovery and some use-inspired and applied research focused (these may look to be future COEs in Australia or CoREs in NZ)*	Monash Centre for Atomically Thin Materials (MCATM); Monash Academy for Cross & Interdisciplinary Mathematical Applications (MAXIMA)
Internal university centres with industry facing applied research and/or consulting focus (customised)	I*A *(special class of IA centre – industry fee for service based, rather than partnership)*	some	Self-funded from generated research or consulting project income with industry (underwritten by the university)		Yes *(applied research mainly with significant focus on consulting and applied research activity with industry, including testing and development)*	Institute of Railway Technology (IRT); Maintenance Technology Institute (MTI)

Australian CRCs: In Australia, CRCs are well regarded IAG centres that include industry, universities and research organisations. CRCs were inspired by NSF ERCs in the USA (Lundequist & Waxell, 2010) and first introduced into Australia in 1990. Since then, more than 212 CRCs have been funded with over AUD$4 billion. According to the CRC Association (CRCA) website, there are currently 33 CRCs in operation[28,29] within the 5850 centres (Table 9) in ANZ universities, given that all CRCs have university partnering. From field observations at the ANZ universities and analysis of CRC-related documents and websites, some of the defining features of CRCs and how they differ from university-led IAG or IA centres (the focus group for this research) are described in Table 13, in terms of the logic of why CRCs are outside the scope of this study.

Table 13 Australian CRCs versus university-led IA and IAG centres.

Australian CRCs	**University led and based IAG or IA centres** ***(the focus group for this research study)***
a) Industry led	University led
b) CRCs develop new technologies, products and services to solve industry problems, accessing all relevant research disciplines for as specific industry sectors. CRCs also support graduates and postdocs to have hands-on industry experience.	University based IAG or IA centres have a broader research scope (applied, use-inspired and basic), with academic staff who must also undertake education for undergraduates and postgraduates. This is in addition to commercialisation and industry engagement activity.
c) A CRC is an incorporated company, limited by guarantee.	IA or IAG university centres are a part of the university, not independent legal entities on their own.
d) CRC do not need to be co-located at a university, but some choose to in order to access research capability and support, and, regardless, they do not report into the university.	All university-led IAG and IA centres are university hosted and integrated into the university.
e) Fulltime (1 FTE) CRC CEO makes the executive decisions and is expected to have experience in business, commercialisation, project management and a technology sector background.	University centre directors are typically academics who may or may not be 1 FTE with the centre, with varying levels of executive management experience and capability; they typically report up to heads of departments, deans or pro vice chancellors, and possess limited executive decision-making power.
f) THE CRC CEO reports to a governance board (GB) with an independent chair and the majority of GB members have to be independent of CRC participants.	University-based IAs and IAGs have industry advisory boards (IABs), not governance boards (GBs).
g) A single CRC typically has more than 20 participants and can include local and international universities, research institutions and industry, including SMEs and community groups.	This can be similar for an IA and IAG, although very few opt for industry membership models on this scale, e.g. EPECentre with over 35 industry members (Lawrence & Bodger, 2008b) and C&P Innovation Program with over 20 members (Lawrence, et al., 2015).
h) Up to 10 years of co-funding from the Australian Federal Government. Note: *It is the only IAG centre program in ANZ with significant funding for this period of time*.	The level and period of funding for an IA centre is variable, while the government core funded IAGs typically range from 3–5 years (Table 12).

[28] Source: http://www.business.gov.au/grants-and-assistance/Collaboration/CRC/about-the-program/Pages/program-evaluation-and-reviews.aspx
[29] Source: http://crca.asn.au/

Other research organisations: The other active participants in centres tend to be Crown Research Institutes (CRIs) in NZ and equivalent research institutions in Australia, including the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Australian Nuclear Science and Technology Organisation (ANSTO) and the Defence Science and Technology Group (DSTG), while in NZ CRIs include GNS Science, the Institute of Environmental Science and Research (ESR), Landcare Research, AgResearch, National Institute of Water and Atmospheric Research (NIWA), the NZ Forest Research Institute (Scion) and Plant & Food Research. These organisations regularly partner with university-based centres and are encouraged to do so as research collaborators. However, they are not permitted by government (funding rules) to lead bids or receive direct funding, as they already have their own funding streams from government, independent of the university sector.

4.4.3 GOVERNMENT RESEARCH AND INNOVATION GRANTS IN ANZ

As an alternative to core funding available for centres from government, IA centres can also access government funding support through research and commercialisation grants available to universities. Many different types of grants are available for collaborative pursuits with industry. Table 14 lists a range of government grants and vouchers currently available in ANZ, collated through analysis of funding agency documents and websites, such as those of the ARC and Callaghan Institute (NZ). From observations at the field-site universities in ANZ and the EPECentre case study, many IA and IAG centres continue to access grants and vouchers.

Nevertheless, some centres have been found to rely predominantly on industry consulting or applied research contracts, i.e. industry fee-for-service, instead of an industry membership approach. This is considered a special class of IA centre, herein referred to as I*A centres (Table 12), which is conceptually based on the findings of this PhD research. The Institute of Railway Technology (IRT) and the Maintenance Technology Institute (MTI) at Monash University, established in 2000 and 1999, respectively, after having transitioned from BHP Billiton, are both examples of I*A centres.[30] [31] This I*A type centre (Table 12) has been found to be viable if three conditions are met: (1) it must be an entity that has transitioned from industry, with a proven value proposition for industry; (2) the centre's management must maintain existing industry relationships throughout, in order to sustain and grow the client base; and (3) the host university must be willing to take the risk and underwrite the core operation of the I*A centre without any guarantees of support from industry.

Table 14 Summary of government grants and vouchers available in ANZ, as at 2016.

Grants and Vouchers	Agency	Characteristics
Entrepreneurs' Programme[32]	Department of Industry, Innovation and Science (Australian Federal Government)	Three components under the one programme: ▪ Accelerating commercialisation: supports the path to market, i.e. commercialisation. ▪ Business management: provides support services to improve industry capabilities and connectivity. ▪ Innovation connections: helping SMEs to engage with researchers and nurture innovation.
Linkage Projects[33]	ARC	Researcher-led collaborative projects with industry.

[30] Source: http://monash.edu/news/show/institute-of-railway-technology-15-years-young-at-monash
[31] Source: http://www.eng.monash.edu.au/mti/about/
[32] Source: http://www.business.gov.au/advice-and-support/EIP/Pages/default.aspx
[33] Source: http://www.arc.gov.au/linkage-projects

CRC-P (Cooperative Research Centres – Projects)[34]	Australian Federal Government	Industry-led collaborative projects with industry.
R&D grants[35]	Callaghan Institute (NZ)	Getting started grants, project grants, growth grants and student grants.
Investment and Funding[36]	Ministry of Business, Innovation & Employment (MBIE) (NZ)	Mission led research investments for NZ: ▪ Annual Science Investment rounds that universities can apply for with industry co-investment; ▪ PreSeed Accelerator Fund (to support early stage commercialisation); ▪ Catalyst Fund (funds international collaboration); ▪ Unlocking Curious Minds (funds innovation to engage young New Zealanders, e.g. schools); ▪ Envirolink (funds environmental research, science and technology).
Grants Victoria[37] Note: similar support exists in other states: New South Wales, Western Australia and South Australia	Department of State Development, Business and Innovation (State Government of Victoria, Australia) Note: similar types of support exist in other states such as New South Wales.	A range of state government schemes to support R&D and innovation, which encourage investments into the state, exporting of opportunities for industry and job creation: ▪ Fund ideas and initiatives for industry; ▪ Develop local and national solutions for industry ▪ Assist in times of hardship (for companies) ▪ Access further information (e.g. funding international trade missions for companies).

4.4.4 INDIRECT GOVERNMENT SUPPORT AND INFLUENCE ON CENTRES

Further to core government funding for centre programs, and research grants and innovation vouchers that are accessible to centres, the other government mechanisms for indirect support are as follows:

- **Government sets policy and legislation:** e.g. 95% renewable by 2025, which in turn challenges industry and university to collaborate on innovative solutions through partnering.
- **Tax incentives:** e.g. R&D tax credit in Australia to incentivise industry to perform more R&D, which includes expenditure on projects with IA centres and charitable donations to an IA centre in a university for non-commercial activities.
- **Media statements**: drive cultural change behaviours and responses, e.g. the rhetoric that universities and industry should collaborate more, which in turn supports IA centre formation and activity within universities.
- **Block grant funding and metrics for universities:** measures to incentivise universities to collaborate with industry on research.

4.4.5 CONCLUDING POINTS ON GOVERNMENT SUPPORT

During the transition to the KE, the government works closely with universities and industry to drive the country's social, economic and environmental development, i.e. the geo-political-socio-

[34] Source: http://www.business.gov.au/grants-and-assistance/Collaboration/CRC/Pages/default.aspx
[35] Source: http://www.callaghaninnovation.govt.nz/grants
[36] Source: http://www.mbie.govt.nz/info-services/science-innovation/investment-funding/current-funding
[37] Source: http://www.vic.gov.au/grants.html#

economic-environmental-technological operating environment. This is reflected in the Triple Helix theory (section 2.2).

A total of 47 out of the 50 universities in ANZ are publicly owned (Table 9), which makes the majority of ANZ universities heavily accountable to government. Nevertheless, the support provided by government, both directly and indirectly, for IA and IAG centres in universities is crucial, and is summarised in the block diagram below (Figure 33). These elements feed into the recommended business model for university-led IA and IAG centres in ANZ universities (Chapter 5).

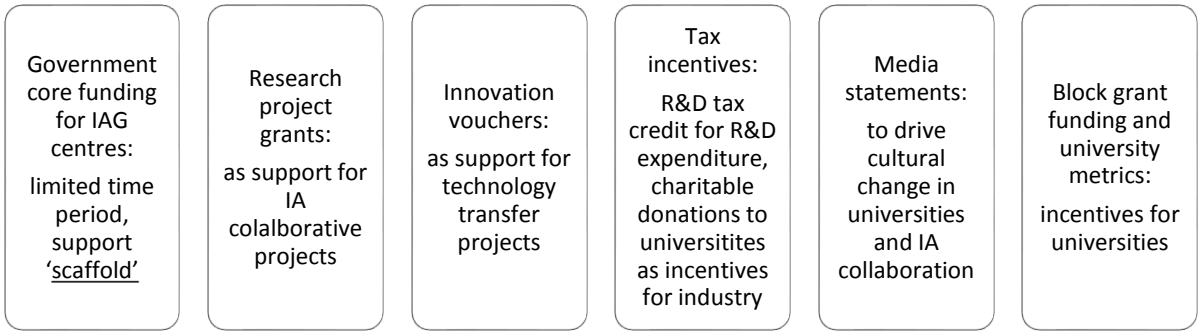


Figure 33 Direct and indirect support through government for IA and IAG centres.

4.5 CENTRE LEADERSHIP AND STRATEGY

A centre's leadership capability and strategy are both key ingredients for success. Moreover, they begin with the centre's leadership team (subsection 2.7.2), who ultimately influence the culture, and set and control a centre's strategy and operations through a strategic plan and a business plan, respectively. Nevertheless, the business model structure is what underpins the strategy and the implementation that follows it (section 2.15). This section provides an overview of key findings around centre leadership culture and strategy.

4.5.1 CENTRE DIRECTORS

During the field observations at the three ANZ universities, it was noted that most S&T centre directors were academic staff. They are often self-nominated on the proposals to establish the centres and appointed to the role pending the success of the proposal. Assessor panels consider the centre director's prior performance and curriculum vitae as core attributes of the selection criteria.

If a proposal is accepted, there is a formal approval process to recognise a new centre within a university. If externally funded, the contractual agreements for a centre may take half a year to finalise. A new centre may lead to an employment contract amendment for the nominated centre director, reflecting the additional responsibility of running a centre, sometimes with a pay increase tied to a set of KPIs determined by the university, industry partners and grant funding rules (if applicable).

4.5.2 TIME COMMITMENT TO A CENTRE

The funding rules for many government grants stipulate a minimum percentage of a centre director's time towards running a centre; for example, for an ARC ITTC the director is required to have a minimum time commitment of 0.5 FTE to centre activities. In practice, this responsibility may be shared with centre managers, deputy directors or co-directors.

Conversely, it was observed that some centres were strategically driven by the university itself, without having a nominated centre director on the proposal. These proposals were generally developed by senior managers and other academics at the university. If approved for funding, these

centres advertised and recruited an appropriate centre director. The recruitment for IA or IAG centres was observed to draw in candidates from both university and industry, e.g. the NZi3 at the University of Canterbury and the GCF Innovation Industrial Institute (GCF I^3) at Monash University. Similar approaches were followed when a centre director resigned or retired. In some instances, existing staff were promoted to the centre director role, such as a centre's deputy director or manager, who were sometimes protégés of the previous director.

Typically, centre directors were noted to be 0.2–0.5 FTE on centre activities, while the balance of their time was split across traditional academic activities such as teaching, research and other administrative duties. Therefore, it was rare to find centres with dedicated fulltime (1.0 FTE) directors Nevertheless, many centre directors were able to negotiate with their respective host department to trade off time commitments between running the centre and performing traditional academic duties. This phenomenon is described in the literature as role strain, which affects all academics participating in centres (section 2.7.3).

These findings (from the previous section) align with the literature on centre leadership and management, which supports the view that centre leaders are the most important indicator of success and that higher reporting lines are better for a centre's profile within the host university (subsection 2.7.2). Another important aspect not mentioned in the literature is that the higher the reporting line, the better the access is to executive decision-making power within the host university. This point will be elaborated on in the section on industry advisory boards (section 4.6).

4.5.3 MANAGEMENT STRUCTURE

A leadership team requires complementary skills. Fulltime centre directors were rare, although the EPECentre has had two consecutive fulltime directors from 2010 to the present. Yet many centres were observed to have fulltime (1.0 FTE) centre managers. Centre managers typically had technical backgrounds in the discipline area of the centre and were often former postdocs with research experience. In fact, very few centres were observed to have professional managers with industrial experience and/or Master of Business Administration (MBA) qualifications, e.g. the centre manager for the C&P Innovation Program at Monash University. Managers were responsible for the overall operation of a centre, as well as implementing portfolio and project management, i.e. managing time, budget, scope and resource allocation.

Centres with a co-directorship structure were also uncommon. These centres typically have two co-directors from complementary academic discipline areas; for example, the C&P Innovation Program had a co-director from chemistry and a co-director from chemical engineering. The co-director approach was discovered to work well in tandem with a dedicated 1.0 FTE professional manager. In the case of the C&P Innovation Program, the team managed a partnership with over 20 companies and multiple projects involving over 50 researchers from both university and industry (Monash University, 2016; Lawrence, et al., 2015). The co-directorship approach aligns with the multidisciplinary aspects described in the literature, e.g. the NSF ERCs have a co-director or associate director approach.

Together, the centre directors and managers, if appointed, represent a centre's core management and leadership team. Conversely, some centres were noted to operate with a fulltime industry-experienced, non-academic centre director performing the manager role and a research leader performing the academic role, such as the Wireless Research Centre (WRC) at the University of Canterbury (University of Canterbury, 2016b).

Many centres were found to rely on business development managers for support on projects and activities with industry (section 4.2), especially in the early stages of setting up, e.g. the Victorian Centre for Sustainable Chemical Manufacturing (VCSCM) received such support from its host university, Monash, during the setup phase (Victorian Centre for Sustainable Chemical

Manufacturing, 2016). While some centres relied solely on their host university business development managers, having no dedicated resource of their own, this was found to be problematic given the ratio of academic staff to staff with a business development role in ANZ universities (ratio of 173:1 (Table 9)). Hence, having a dedicated centre manager is a must for an IA or IAG centre in ANZ.

4.5.4 REPORTING LINES

Centre directors generally reported to heads of departments or faculty deans and, in rare instances, to pro vice chancellors, e.g. the Monash Sustainability Institute and the eResearch Centre at Monash University. Additionally, many centres within ANZ universities had industry advisory boards (IABs) for strategic endorsement and as a means of keeping stakeholders informed. However, formal reporting lines for centre management, as stipulated in employment contracts, were always within the university, as a centre's legal status is as an entity of the host university. The host university carries the underwritten risk for a centre and therefore ultimately has veto power over a centre. This overarching power is not highlighted in the current literature, but is very important given that it delineates a key management consideration for centres.

4.5.5 LEADERSHIP CULTURE OF A CENTRE

Centre directors of S&T centres involving industry were expected by university and industry stakeholders to have exceptional entrepreneurial leadership skills, and experience in managing collaborative teams and driving strategy involving industry, university and government stakeholders. Centre directors were also required to have demonstrable track records in delivering successful initiatives and outcomes. The management and leadership experience of academic staff transitioning to centre directors was found to be limited to a few years, heading their own research labs with honours students, PhD students and postdocs. Contrastingly, some centre directors were found to have extraordinary vision and strong industry collaboration experience.

Some directors demonstrated a track record in entrepreneurial pursuits (e.g. commercialising research), and the ability to drive bold, strategic initiatives with industry from within a university environment, take strategic risks and maintain strong industry and government linkages. Centre directors were authentic in their leadership and took great care in building altruistic relationships with key internal and external stakeholders, were able to negotiate external funding, recognised team contributions, empowered team members, challenged the status quo for improvements, were responsive to opportunities and viewed collaboration with industry as a long-term strategic endeavour for win–win outcomes.

The world's most highly cited academic engineer, Professor Robert Langer of MIT, spoke with the International Business Times (14 October 2015) on getting funding for research and having the right business leadership to drive a venture (e.g. a centre):

> You're always trying to raise money. In some places, you can raise money on sales. Here, you're raising money on hopes that often can be fulfilled but unless you get the money, you have no chance to do it. It's not like these things are easy to do … it's easy to fail … the hardest is finding the right CEO. I want to make sure they're driven. I would like them to be charismatic.[38]

Some adapted to the role of centre director well and others were observed to find it challenging. This can also happen to centre directors with strong industry backgrounds who get recruited into universities to run centres:

[38] Source: http://www.ibtimes.com/robert-langer-top-mit-biomedical-engineer-father-30-companies-how-launch-successful-2141263#.VjDqY-Atf9E.twitter

> The NZi3 established in 2009 is NZ's ICT Innovation Institute hosted at the University of Canterbury. It was established with a government co-investment of $10m for the NZi3 building, which was aimed to create a meeting place between university and industry for ICT innovation. It received industry support from Tait Communications, HP, IBM and Jade. However, its inaugural director, who was described in the media as having an impressive international industry track record, resigned soon after it was launched. The University's deputy vice chancellor at the time stated in a press interview 'the leadership for the future needs to take account of the university's agenda, looking to get really strong buy-in from a great range of our academics … we might need a different style of person to do that'.[39]

Comparatively, it has been found that the EPECentre leaders involved a subset of academic research associates who were regarded as an 'inner circle' of trusted advisers (key internal stakeholders) for the EPECentre. These academics were valued and supported by the EPECentre leadership team and were involved in collaborative projects. In return, this informal committee of research associates provided valuable feedback on the proposed direction of the EPECentre's portfolio of activities in education, research and industry interaction.

Overall, these findings reveal the need for intrapreneurial leadership qualities at the helm of a centre. The concept of an intrapreneurial leader was first introduced by Pinchot (1985), who describes such leaders as those who operate out of large organisations and drive entrepreneurial initiatives from the inside, while overcoming internal resistance and roadblocks along the way. According to Pinchot (1985), intrapreneurs personally commit themselves to a vision, take things into their own hands and pull the team along with them. Such an approach lends itself to the transformation of failed opportunities into valuable ventures (Pinchot, 1985). This type of drive was observed to inspire participation and rally support from both academia and industry; for example, when the original proposal for the C&P Innovation Program failed in 2014, the leadership team persevered with the vision, resulting in an even better outcome in 2015 to successfully establish the centre.

Conversely, from the perspective of the host university, centre leaders need to be managed differently to regular academics and should be viewed as serial innovators (Griffin, et al., 2012) who need to be given a reasonable amount of freedom within the university to transcend structure (departments and faculties) in order to flex their wings and be intrapreneurial, as described by Pinchot (1985). Griffin et al. (2012) describe serial innovators as those who do not conform to bureaucracy, but deliver breakthrough results in large organisations. The same could be said about successful centre leaders. Therefore, centre leadership teams should ideally possess the qualities of an intrapreneurial serial innovator. Current literature does not emphasise the leadership team of a centre nor the concept of serial intrepreneurship, but rather describes a single leader 'at the helm'.

4.5.6 STAFF EMPOWERMENT

Centre leadership creates a culture that rewards results, with flexibility for its staff instead of a nine-to-five mentality (Semler, 2003), by acknowledging them as knowledge workers who can work from anywhere at any time (section 2.1). The leadership of a centre sets the culture. As an example, the EPECentre cultural philosophy was one that focused on being action orientated and entrepreneurial, where risks were assessed and mitigated. New opportunities at the EPECentre were explored and exploited where possible, where they aligned with the three strategic pillars of (1) research; (2) education; and (3) industry interaction.[40] The EPECentre staff culture was strongly aligned with having a 'can do' attitude.

[39] Source: http://www.stuff.co.nz/the-press/news/our-communities/2720724/Canadian-quits-as-head-of-innovation-institute

[40] Source: Lawrence, J., 2009, PhD Seminar: "A Model for a Centre of Excellence – The EPECentre Way", University of Canterbury, New Zealand.

Staff empowerment, according to Blanchard et al. (2001), is "essential for effective organizations in today's dynamic and complex world'' (p. xi). Within centres, this means everyone is fundamentally a knowledge worker (Drucker, 1999) and centre directors ideally must not be inflexible, letting go of tendencies to micro-manage. Ultimately, it is about creating a collaborative centre where participants and centre staff can be supported to perform to the best of their abilities, as was observed at a number of centres across the ANZ field-site universities. This is a point that is strongly made by Welch (2005): "before you're a leader, success is about growing yourself. When you become a leader, success is all about growing others" (p. 61). It is about helping "people reach their full potential" (Blanchard & Johnson, 2004, p. 39).

4.5.7 CENTRE STRATEGY AND OPERATIONS

A key observation at the field-site ANZ universities was that a university cannot artificially create a centre that is excellent instantaneously. It has to be set up properly to start with and nurtured towards a desired direction, underpinned by a strategy that the staff and stakeholders believe in; e.g. the EPECentre had a simple (one-page) three-year strategic plan that set out its vision, goals and objectives around three key pillars, research, education and industry interaction.[41] These three pillars were held in equilibrium, in terms of the centre being able to offer a range of value-added propositions for its industry and university stakeholders depending on their needs and wants from the centre.

Another key observation was that a centre should be nimble and flexible to opportunities. Hence, in the case of the EPECentre it was found that an annual (one-page) business plan was produced with key deliverables to deliver on the strategy. The plan was progressively elaborated on by the management team and the IAB as prospects arose, so that the centre could respond quickly to opportunities. Part of the nimbleness of the EPECentre was in being aligned with a single host university, rather than being a multi-university centre (i.e. a centre hosted between several universities across multiple geographies), so decision-making was cleaner and the EPECentre having university executives on the IAB meant that approvals were expedited.

It was the role of the IAB of the EPECentre to evaluate activities against the strategic plan for the three key pillars. The implementation of strategy, i.e. taking action and not just talking about what needed to be done, was found to be key. In fact, the simple one-page approach seemed to help key participants get on board with the direction and vision of the centre. Therefore, the evidence suggests that it would be a mistake for centres to: (a) not have a plan; (b) assume that the government funding proposal is the plan (a common practice in academia); or (c) develop complex documents as plans. "A mushy mission statement is an indication that a company doesn't know where it's going" (Trout & Rivkin, 1999, p. 91) and the same rules apply for a centre. The importance of strategy and the execution of strategy are not explicitly discussed within the literature on centres; rather, they are assumed.

Furthermore, it was found during the EPECentre case study that striving for excellence and financial sustainability meant setting high standards of work output. This included having professionally managed industry projects (i.e. being on time and on budget, to meet the scope), value-added initiatives (e.g. annual visit to Nukuhau Marae in Taupo to expose students to Māori culture), ambitious research programs (e.g. development of power quality guidelines for NZ) and innovative showcasing events to attract a crowd and communicate the value of participating in the centre to stakeholders. What this shows is that this centre's inherent business model, i.e. structural blueprint (section 2.12), enabled a wide range of creative and innovative strategic approaches to be taken in combination within its pillars of research, education and industry interaction.

[41] Source: Lawrence, J., 2009, PhD Seminar: "A Model for a Centre of Excellence – The EPECentre Way", University of Canterbury, New Zealand.

This is exemplified by the EPECentre's annual R&D expo, with inspirational exhibits that drew in the media and a range of stakeholders. By way of example, the 2010 expo included a public outdoor demonstration of the world's longest manmade lightning bolt[42] (Figure 34). It attracted significant media interest and hundreds of attendees. Conceptually, it was inspired by the public showcases of the likes of Nikola Tesla (1856–1943) and Thomas Edison (1847–1931).[43]

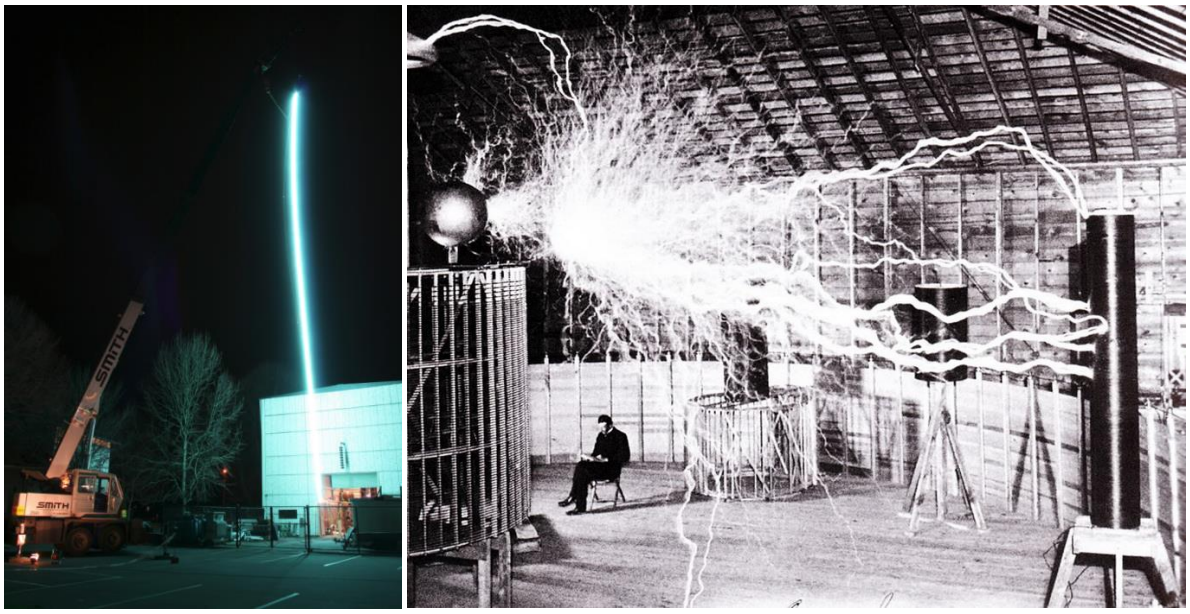


Figure 34 Preparations at the EPECentre R&D Expo 2010 (image on the left) for the longest manmade lightning bolt public demonstration (photo source: Wade Enright et al. 2010); Nikola Tesla (image on the right) with his tesla coil experiment (source: Wikimedia Commons).

The EPECentre approach of large-scale public demonstrations of S&T is uncommon for centres and emphasises tactics that could be used to draw and inspire centre stakeholders together towards the common vision. The EPECentre was the only centre observed across the ANZ field-site universities to use such manoeuvres to achieve its strategic goals in research, education and industry interaction.

4.5.8 SUMMARY OF CENTRE LEADERSHIP AND STRATEGY IMPLIMENTATION

Centre leadership summary

The literature identifies centre directors as the key to the success of centres (subsection 2.7.2). However, the findings from this research indicate that there is more to this. It is the leadership team working in unison, consisting of a centre director and a centre manager or a combination thereof, with complementary skills and experience. This is the key driver of the success of a centre, supported by a broader group of participants including the IAB.

The literature largely ignores the role of centre manager in the leadership function of a centre and nor is there any recommended specification for a centre manager other than the general unwritten assumption that it will be 'someone appropriate'.

Observed in practice was a tendency for some centres to appoint as centre managers postdoctoral fellows or temporary academic staff, who are either untrained and/or inexperienced in management,

[42] Source: https://www.youtube.com/watch?v=9DOsKro3OqI

[43] Source: http://news.nationalgeographic.com/news/2013/10/131003-nikola-tesla-surprising-facts-statue-museum-science/

rather than professional managers with management experience and qualifications. Furthermore, some scholars such as Sá (2008) (subsection 2.7.2) indicate that many centre directors lacked management experience on the job. Therefore, one solution is for host universities, via their human resource departments, to offer executive training specifically catering for centre directors and managers as a part of their induction or ongoing professional development.

Findings suggest that a centre should have a fulltime director and/or a fulltime manager as a minimum, as a part of its organisational structure. Centre management should display qualities of serial intrapreneurial leadership, in order to drive strategy, rally participants, empower staff and build internal and external relationships.

Finkelstein (2003) sums it up well: "the scorecard for new ventures is not determined by how stellar the resumes of the management team are. Don't lose sight of what counts: strategy, capabilities, customers, and competitive advantage." (p. 51).

The inherent business model (section 2.12) for a centre underpinned by a simple strategic plan (typically three years) endorsed by its stakeholders is unique to a particular centre. This then informs an annual business plan to deliver on the strategy. Moreover, this business plan is progressively updated over the course of 12 months, to drive operations in the same direction as the strategy, which is led by the centre's management team and endorsed by its IAB. Therefore, the business model leads to the business strategy, which in turn drives the (operational) business plan. This can be described by the block diagram in Figure 35, where the research output presents a recommended business model (Figure 26) for S&T IA centres within ANZ universities in the KE (2.1), which in turn leads to a strategic plan (endorsed by the IAB) and a business plan to implement the strategy (progressively updated during the course of operations and progress reviewed by the IAB).

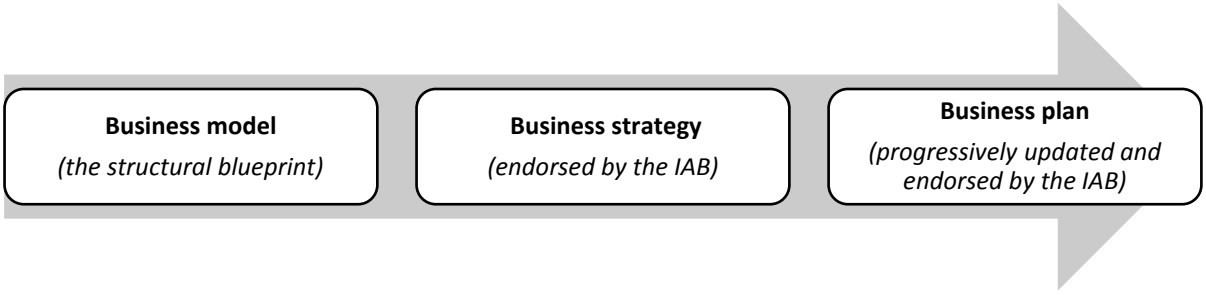


Figure 35 Connectivity between the business model, the business strategy and the business plan for a centre.

4.6 INDUSTRY ADVISORY BOARDS FOR IA CENTRES

The governance layer in the commercial world is a control measure over the management of an organisation to ensure that the shareholders' interests are responsibly managed (Ferguson & Ferguson, 2000). Those on the governance board (i.e. board members or directors) of an organisation carry fiduciary responsibility, which means that they are personally legally liable and responsible on behalf of the organisation to undertake due diligence, act in good faith and conduct themselves properly in terms of position and information (Baxt, 2012).

Oversight for a university-led IA centre in ANZ universities is via its IAB. However, in the university environment the IAB is not a governance board. This is because centres do not have legal status and are part of the host university. Instead, the advisory role on the IAB allows "individuals to offer their expertise without being concerned about taking on directors' formal duties and responsibilities" (Australian Institute of Company Directors, 2013, p. 33). Moreover, unlike in a commercial governance operation, the IAB and its members are appointed by the IA centre director and the

university, by consensus. The university has ultimate executive power, control and liability for an IA centre that is within an ANZ university (i.e. hosted and led by the university). Hence the role of the IAB comes after the role of centre leadership and management (section 4.5). Contributions made by an IAB to an IA centre are outlined in the next sections of this chapter.

4.6.1 THE ROLE OF THE INDUSTRY ADVISORY BOARD

This theme of industry partnered guidance, i.e. the IAB, is particularly prevalent in the research findings. In the case of the EPECentre, it has been found that the IAB members, many of whom were alumni of the University of Canterbury, were pivotal for the EPECentre in leveraging their individual relationships with other senior executives (i.e. their peers) in other companies by linking into their professional network of contacts. They helped to introduce the value proposition of the EPECentre to potential new members. Some of the approaches used by the IAB members for potential new members included introductions to EPECentre management and invitations to visit the University of Canterbury. IAB members also used marketing collateral provided by the EPECentre.

Generally, the IABs for IA S&T centres in the three field-sites have typically been found to include representatives from industry, government and the host university. However, a number of the centres with industry membership consortiums, such as the EPECentre and the C&P Innovation Program, had senior executive level industry representation on the IAB and were chaired by a senior executive from the end-user membership consortium of the centre. Furthermore, all the industry representatives on the IABs for these membership-type centres were specifically from end-user industry organisations that were members of the centre. Industry associations were also often represented on centre IABs.

IABs generally demonstrated a will to create impact for the greater good of the industry sector. It is evident from the following statement what the strength of a cohesive centre leadership with a supportive IAB can achieve:

> The NZ Minister of Science, Research and Technology, Hon Dr Wayne Mapp, in a keynote address at the University of Canterbury on 30 September 2010, stated that he was 'impressed with how the board and staff at the EPECentre had worked with industry partners to make it a centre of national excellence'.[44]

Particular emphasis was placed by IABs on the impact of a centre's activities on students and graduates, and the creation and transfer of knowledge into their specific industry sector. The ongoing funding for a centre, industry, education and technology trends, government changes and business processes within a host university were found to be key concerns for an IAB that provided strategic guidance for a centre.

Although these boards are advisory, there was an expectation for transparent reporting on financial matters. The reporting format style for IAB meetings to meet the expectations of members was often a learning curve for centre directors and managers. There was often confusion at IAB meetings, given the use of calendar-year reporting in universities versus financial-year reporting in industry, and the way budgets were managed across faculties and departments. Activity-based reporting in universities versus project-based reporting in industry and how overheads were costed were other areas for regular IAB debate. Nevertheless, it was up to centre directors or managers to bring clarity on such matters. In fact, none of the three field-site ANZ universities possessed templated terms of reference (i.e. best practice guidelines) for the operation of IABs. Each centre appeared to have developed its own terms of reference for an IAB, without the benefit of lessons learned from other IABs.

[44] Source: http://www.comsdev.canterbury.ac.nz/chronicle/2010/ChronVol45-15.pdf

There were found to be some centres that had more university or independent (i.e. professional board directors) representatives on their advisory board than from industry and were not referred to as IABs. These centres typically did not have a membership consortium model and many were chaired by a nominated senior university representative, the director of the centre or a paid independent chair. Often government funding rules or agreements stipulated the makeup of such a board:

> According to the Cooperative Research Centres Association (CRCA), Dr Tony Peacock (4 April 2012), drawing on experience with CRCs involving industry and universities, he articulates the need for strong governance, stating on the CRCA website 'Scientists will often simply divide a pot of money and do their own thing if leadership and direction is missing. In governing applied research, you must get the end-users in the driver's seat'.[45]

The IABs for a number of centres went a step further than being purely advisory, in terms of executive reach. For example, the EPECentre and the C&P Innovation Program included key university decision-makers on the IAB, such as pro vice chancellors, heads of departments and portfolio directors.

The IAB of the EPECentre met every quarter, when an annual business plan was progressively elaborated to respond to opportunities, underpinned by an overarching strategic plan. It is clear from a number of these centres that the role of an IAB is to endorse strategy and to ensure that stakeholder expectations are met. The IABs, in the cases examined for the EPECentre and the C&P Innovation Program, provided strategic advice to the centre leadership and reviewed and endorsed strategic plans and business plans, while operating with transparency on their contractual obligations, financials and project outputs, within specified commercial-in-confidence boundaries, e.g. details of IP and specific objectives of research projects for an industry participant were kept confidential, with only high-level reporting on the activity to the IAB.

The IABs with end-user membership consortiums had the following characteristics:

- A nominated or elected chair and secretary, with 5–15 IAB members, inclusive of the chair
- Reporting by the centre director and manager to the IAB
- Professional industry-standard board-paper reporting formats, with transparency to meet the expectations of representatives on the IAB, sometimes including finances
- Frequency of meetings varied from annual to quarterly between centres, with a general requirement for at least 50% attendance by IAB members to achieve a quorum
- The IAB members, and in particular the chair, provided leadership mentoring and support for the centre directors and managers
- The IAB representatives were appointed by centre directors, nominated by centre stakeholders or a government funding agreement, or in some instances voted in by industry consortium members.

From the perspective of industry, one IAB member of a collaborative centre stated eloquently, "Show us the commercial benefit of the centre's activity and we will keep on investing and invest more".

4.6.2 SUMMARY OF INDUSTRY ADVISORY BOARD FINDINGS

An IAB can be thought of as a protective enclosure for a centre, guarded by the centre's key stakeholders. It is primarily there to provide high-level oversight of a centre, but also to provide wise counsel to centre management on strategic direction and objectives. The majority of representatives on the IAB ought to be executive-level industry representatives, e.g. CEOs, vice presidents, and general managers, with an end-user industry chair, and should ideally include a university representative who ultimately has executive power within the centre. The end-user industry chair should be unpaid and, contrary to standard practice, should not be independent of the centre's

[45] Source: http://crca.asn.au/research-to-innovation-the-role-of-multidisciplinary-teams/

membership in terms of their representation. This enables the chair to lead by example with the heart of a volunteer, like the chair of the EPECentre IAB and the chair of the C&P Innovation Program IAB.

Such a combination not only achieves a strategic focus, but also enables the IAB to have quasi-governance, with the inclusion of university stakeholders, to align the direction of the centre and the university. Furthermore, a terms of reference for an IAB should be considered standard practice. These concepts are not discussed by scholars in the literature.

4.6.3 THE IAB VERSUS THE R&D STEERING COMMITTEE

The literature discusses IABs focused on R&D projects tied to centre funding, and many scholars' reference R&D managers as being representative on the IABs of centres. While this is important, there seems to be a lack of separation in the literature between the strategic operation of a board and the research portfolio. In fact, both are treated as one in the same in most cases.

Key observations made during the study point to the need for IA centres in ANZ to adopt a practice of separating out the strategic IAB from the R&D steering committee. This means that executive-level industry leaders will sit on the IAB, while industry R&D managers will sit on the R&D steering committee. This would make sense for ANZ, where executives have been found to have stronger interest in strategy, innovation, training and corporate social responsibility (CSR), while R&D managers are more technically focused and less interested in broader strategic issues (section 1.2).

However, given the inherent nature of innovation, i.e. open or closed modes with multiple variations, as stated in the literature on collaboration (section 2.4), it would appear to be more sensible for centres to abolish the concept of an overarching R&D steering committee and instead create multiple R&D steering committees on a needs basis for specific programs and projects.

This is the approach that was used by the EPECentre and subsequently by the C&P Innovation Program. It reduces the need for complex IP arrangements and confidentiality, and enables industry to collaborate at the strategic level for the higher purpose (altruistic) goals of the centre, which in the case of the EPECentre spanned research, education and industry interaction. Meanwhile, within the research portfolio closed mode innovation approaches were utilised at the R&D project level, which was more suitable for the management of commercially sensitive IP. This is in contrast to the NSF I/UCRCs, where all industry members co-sponsored the research and co-shared in the IP, which appears to be less flexible and less desirable for industry (section 2.14).

4.7 THE CENTRE TEAM AND RESOURCES

A centre's team and resources are its capability hub. The following section presents results and discusses implications pertaining to multidisciplinary teams, professional project management and the concepts of hybrid academics and industry professors, with respect to IA centres.

4.7.1 INVOLVEMENT OF MULTIDISCIPLINARY ACADEMICS

Observations indicate that many centres engaged academic staff across various departments, faculties and even other centres, in order to extend the centre's multidisciplinary research capability. Furthermore, some centres had research collaborators across a range of other national and international research institutions and universities. The variety of approaches for multidisciplinary capability within some of the centres across the field-site ANZ universities are shown in Table 14, where the types of R&D are defined as: consulting (C), development (D), basic research (R_B), applied research (R_A), and use-inspired basic Research (R_{UI}).

This is because industry facing real-world challenges is multidisciplinary. As per the literature, this is a hallmark of collaborative centres (section 2.11.3). The siloing of capability into discrete departments is an artefact of teaching arrangements of a university (section 2.3). Departments on

their own are not optimised for the purposes of real-world problem-solving, whereas centres can be (Table 15).

Industry collaboration requires a thematic approach to problem-solving, e.g. a company working in food manufacturing would be interested in nutrition, food chemistry, packaging, mechanical automation, marketing, econometrics and international trade policy. An academic department does not have this breadth of capability on its own. A centre, on the other hand, can be flexible and draw on key capabilities across a university and research collaborators as required.

Table 15 Examples of S&T Centres within ANZ universities with different approaches to draw in multidisciplinary capability.

S&T centre name:	**Centre type?**	**Multidisciplinary capability (departments, faculties, facilities and external research institutions)**	**Type of R&D performed?**
MAXIMA (Monash Academy for Cross & Interdisciplinary Mathematical Applications)	A	School of Mathematics, Faculty of Information Technology, Faculty of Engineering and Department of Econometrics & Statistics. To engage on a range of applications including manufacturing, transport, ecology, medical research, health, weather and energy.[46]	R_A, R_{UI}
C&P (Chemicals & Plastics) Innovation Program	IAG	School of Chemistry, Department of Chemical Engineering and Department of Materials Engineering to service the needs of the chemicals and plastics industries including speciality materials and chemicals, energy, food & agriculture, and fast-moving consumer goods.[47]	R_{UI}
Victorian Centre for Sustainable Chemical Manufacturing (VCSCM)	IAG	A consortium of capability, including: Chemistry, Chemical Engineering and Materials Engineering at Monash University; CSIRO and the Environmental Protection Agency (EPA) Victoria.[48]	C, R_A
IRT (Institute of Railway Technology)	I*A	A specialist centre with self-contained, embedded multidisciplinary capability integrated within the Centre's staff, e.g. specialists in instrumentation, wheel–rail interface and materials. It does not need to venture out, given the in-house capability available to support the core needs of the transport industry, on a fee-for-service basis.	C, D, R_A

[46] Source: https://platforms.monash.edu/maxima/index.php?option=com_content&view=article&id=84&Itemid=196
[47] Source: https://www.monash.edu/cpmin
[48] Source: http://vcscm.org/

EPECentre (Electric Power Engineering Centre)	IA	It has core centre staff, i.e. hybrid academics with specialist applied capability (e.g. power systems), and works closely with its host department (i.e. research associates) and accesses other researchers at the university and externally, on a needs basis. This multidisciplinary approach serves the needs of the broad electricity industry including electricity generation, transmission and distribution, manufacturing, consulting and contracting.	C, D, R_B, R_A, R_{UI}

4.7.2 PROFESSIONAL PROJECT AND RESOURCE MANAGEMENT

From the EPECentre case study, it can be seen that professional project and portfolio management was strongly emphasised, i.e. the balancing of centre resources, including staff and infrastructure, project scope, time and budget. This can be represented by a modified 'project management iron triangle' (Figure 36), which includes resources (R) in the middle, where the dependencies between elements are represented, e.g. when scope (S) expands, so does the time (T) taken to perform the work, which may mean greater resources are required, higher risk or changes to the output quality of the work, and a larger budget (B) (Project Management Institute, 2013).

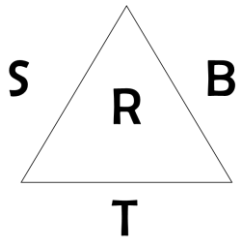


Figure 36 Modified 'project management iron triangle' with resources (R) in the middle, with respect to time (T), scope (S) and budget (S);

Note: alternatively (Figure 36), quality (Q) and risk (r) can be substituted for resources (R) in the middle of the triangle, to show the interdependence of scope, time and budget.

The EPECentre management was responsible and accountable to the IAB and the host university for ensuring that professional management approaches were utilised for its activities. This included proposal development, project negotiation, budget and cash flow management, resource allocation, contract management, IP management, academic freedom to operate (FTO), commercial confidentiality, stakeholder management, scope management, time and milestones management for deliverables.

Resources of the EPECentre included a director, a manager, 3–4 research engineers (i.e. hybrid academics; section 4.7.3), technical support assistants and administrative assistants – typically a team of 5–8 core staff over the period 2005–2015. However, the broader EPECentre team (over 30 individuals) that was mobilised on projects included many academic and technical research associates (usually from various departments across the host university, drawn together by a common interest in the research area). In addition, centre staff resources were drawn from research assistants, postdocs and postgraduate students, as well as casual employees. Likewise, visiting academics, industry project participants, collaborators from other universities (local or international)

and industry consultants were all flexibly available for deployment on EPECentre research projects on demand.

The responsibility was on the centre director and manager to lead and manage (demonstrating intrapreneurial leadership; subsection 4.5.5), engage across this broader group, motivate them to work on multiple projects, give them experience in industry–university collaboration, build team culture and drive the objectives of the centre with industry for impact.[49] Furthermore, the EPECentre staff were found to be involved across activities in three key pillars: (1) education, (2) research, and (3) industry interaction.[50]

4.7.3 HYBRID ACADEMICS AND INDUSTRY PROFESSORS

Hybrid academic staff of a centre are research staff with strong industry experience employed by the centre to specifically work with industry and provide research translation, e.g. EPECentre research engineers at the University of Canterbury had their salaries underwritten by the EPECentre's membership funding. They were complementary to postdocs, postgraduate students and academic or technical staff (research associates) linked to the centre.

These hybrid academic staff were observed during the field-site studies at ANZ universities, at the EPECentre in the University of Canterbury (first introduced in 2005[51]) and at Monash University's new Food Innovation Centre (FIC) in 2016. The FIC, which evolved out of Mondelēz International,[52] had an industry professor as the centre director (a former R&D executive from industry) and was expected to have a team of industry specialists (hybrid academics) once it became fully operational in 2016.

Hybrid academics display the ability to work on industry projects at the pace of industry, translate research for commercial applications and collaborate with both industry and academic staff. They are also able to draw on the depth and breadth of multidisciplinary academic capability (e.g. science, engineering, business) to tackle real-world challenges. Having hybrid academic involvement meant that regular academic staff were able to keep their focus on university research and teaching duties, while collaborating and often undertaking paid consulting across a range of industry projects and R&D programs worked on by hybrid academic staff.

The EPECentre leveraged university policy which allowed up to 20% of an academic staff member's time to undertake consulting activity. Hybrid academic staff were also able to mentor and train postdocs and research scholars, as well as co-supervising postgraduate students. Furthermore, the hybrid academic staff observed at the EPECentre undertook joint publications with academics and industry researchers, and co-authored major research proposals.

Overall, the hybrid academic concept allows centres to work across the R&D continuum, i.e. C, D, R_B, R_A and R_{UI}, and adds value for both industry and academic participants. It is a unique concept for centres that has not been discussed or realised in the literature. The industry professor concept has been considered, but only in the context of them being within academic departments and not within S&T centres; industry professors are akin to the concept of 'pracademics' (Posner, 2009) and 'professors of practice' (Etzkowitz, 2008). Another aspect to note is that academic staff are able to utilise the 1/5 rule, which originates from MIT (Etzkowitz, 2008), to allow them to consult for 20% of their time, and this can be leveraged to provide guidance on industry R&D projects managed by a centre and resourced by hybrid academics.

[49] Source: http://ir.canterbury.ac.nz/handle/10092/402
[50] Source: Lawrence, J., 2009, PhD Seminar: "A Model for a Centre of Excellence – The EPECentre Way".
[51] Source: http://www.epecentre.ac.nz/people/index.shtml
[52] Source: http://www.mondelezinternational.com.au/media-centre/news/mondelez-food-innovation-centre-phase-two

The traditional approach in centres of mainly using postdocs and postgraduate students can be used to enhance this approach, which makes it a comprehensive method that achieves many goals, e.g. research training for students, industrial experience for postdocs, consulting pay for academics, valuable outputs for industry, revenue for the centre and a positive reputation for the university. This could be summed up as producing KE impact via an entrepreneurial university (section 2.3).

A limitation is being unable to offer permanent contracts to hybrid academics and industry professors. These groups are typically on a parallel career track to that of academic staff, but without the opportunity to become permanent staff. However, this can be countered with competitive market salaries and freedom to operate on innovative projects of interest. This empowerment can be attractive for intrapreneurial knowledge workers (Drucker, 1999; Pinchot, 1985; Blanchard, et al., 2001), having their positions underwritten by a centre or a department to give them peace of mind. From a psychological perspective, Maslow's Hierarchy of Needs suggests that people need their lower order needs met, such as job security, in order to be able to perform higher order work, such as R&D (Atkinson, et al., 1953).

4.7.4 SHOPFRONT AND INFRASTRUCTURE

In terms of infrastructure, i.e. laboratories and equipment, as well as a shopfront for a centre to use as a base of operations, it has been found that many centres managed infrastructure needs through the arrangements made with the host department at the host university. The EPECentre went a step further and had an MoU (section 4.2.3) with the host department for these requirements:

> At the opening of new premises of the EPECentre (30 September 2010), the EPECentre Chairman Peter Berry stated in an article 'the new offices provided a dedicated space and "vital shop-front and hub" for EPECentre, industry, schools, academics and students from all engineering disciplines'.[53]

This highlights the importance of human-to-human interaction and geographic proximity for team work, brand visibility and IA collaboration.

4.8 INDUSTRY MEMBERSHIP CONSORTIUMS AND PARTNERSHIPS

The concept of modes of industry partnership in centres is essential to this research topic. The partnering of industry is analogous to a 'tower' that provides strength and resilience for an IA centre. Therefore, the following section outlines research findings and discusses implications pertaining to ANZ industry participants, the modes of participation in centres and membership consortiums for centres.

4.8.1 ANZ INDUSTRY PARTICIPANTS AND OTHER STAKEHOLDERS

Incentives for industry to participate with universities have been found to be encouraged by government through tax incentives, which vary from time to time (section 4.4). Although these are not specific to the university sector, the incentives do have a resonance with industry and university collaboration. This can be either for philanthropic donations via a charitable trust under a CSR banner or R&D tax credits for R&D expenditure, both of which are available in Australia and NZ when the eligibility criteria are met by a firm (Inland Revenue Te Tare Taake, 2016; Australian Tax Office , 2016). Contributions can also be made to university centres by way of sponsorship, which usually carries no tax benefits to a firm and can be either commercially motivated or CSR driven. Nevertheless, IA centres have the ability to leverage these mechanisms for the value proposition of forming a membership consortium (i.e. a partnership) with industry.

[53] Source: http://www.comsdev.canterbury.ac.nz/chronicle/2010/ChronVol45-15.pdf

The types of organisations in ANZ range from SMEs to large companies and multinationals. However, the vast majority are small SMEs (section 1.2). Many centres and university representatives said that the nature of working with SMEs meant a heavier demand on university resources, as many of the smaller SMEs lacked funding capacity and yet required greater support than larger companies. However, a goal for ANZ IA collaborative centres is to help convert medium-sized SMEs into large-sized (ANZ-owned) multinationals and help small-sized SMEs (defined as having fewer than 20 employees) grow into medium-sized SMEs (defined as having between 20 and 200 employees), given that 99% of firms in ANZ are SMEs (Australian Bureau of Statistics, 2002).

This has to be at the same time as building deeper relationships with large multinational companies, so that SMEs can learn from and partner with multinational companies. Therefore, the ideal model for IA centres in ANZ universities ought to be able to accommodate SME engagement with large multinationals, along the global value chain of the specific industry, which is relevant for competitiveness in the KE and a key consideration for the recommended business model for S&T centres in ANZ universities (section 2.1 and 2.15; Chapter 5).

On the plus side, SMEs were described as more flexible and the ones that engaged with universities were perceived to be more innovative and globally orientated, seeking diversification and differentiation opportunities (e.g. Haymes Paint in Australia, as a member of the C&P Innovation Program), whereas those not involved with universities were perceived to be less innovative and thought to be fully occupied with operating a small business and lacking the bandwidth to engage with universities.

Conversely, larger ANZ-owned companies (national or multinational) were described as being less constrained by funding and perceived to be the ideal partner for universities, with direct access to key executives such as CEOs and CTOs (Chief Technical Officers), as well as R&D activity all concentrated within ANZ, e.g. Cochlear, Visy, Fonterra, Transpower NZ and Axieo.

Lastly, foreign-owned multinationals were generally viewed by university and government to have sophisticated approaches to innovation. However, the bulk of multinationals operating in ANZ (e.g. PerkinElmer) were found to be sales and marketing focused for regional product distribution. They usually possessed technical product support capability in ANZ, e.g. maintenance services and testing.

According to interactions with representatives of multinational firms with the researcher as a participant-observer in the field-site universities, most of the R&D of the multinational firms was indicated to be performed overseas in countries such as the USA, Germany, China and the UK. Still some multinationals were found to have manufacturing operations in ANZ, but only a few were found to have globally recognised R&D departments in ANZ, e.g. Mondelēz, Agilent Technologies, 3M, GSK and PPG.

Many industry segments of ANZ operate under a perceived threat of jobs being shifted overseas, e.g. China, Vietnam and India, particularly in the manufacturing sector. This is a message that is routinely touted by the ANZ media. From the perspective of an academic who was interviewed for this research study, “Industry in Australia is very different to industry in the USA. We have SMEs mainly, whilst R&D of big companies are almost all overseas based”.

Many researchers across the field-site ANZ universities liked the idea of supporting and helping SMEs. Sometimes this meant doing pro bono work or delivering more than what they had paid for, and providing easy access to new IP in order to help SMEs go forward. However, a reasonable return was expected for any serious contributions. Contrastingly, many researchers felt differently about large multinational companies and were less altruistic towards doing pro bono work for them.

Anecdotally, having the academic population show willingness to help SMEs is a positive development for ANZ and is grounds for future research to validate. However, what is clear is that

more effort is needed by government to facilitate support for SMEs through universities, with specific incentives for universities. IA centres could play a role by building value chain membership consortiums involving SMEs with leveraged co-funding from government and in-kind support from host universities, to help SMEs get ahead, i.e. converting small SMEs into medium and medium SMEs into large (ANZ-owned) multinationals, in line with the value chain concepts of Porter and the five forces model (subsection 2.16.1).

Multinationals could play a role in centres by sharing innovation approaches with SMEs and developing partnerships with SMEs. Centres that bring SMEs together with multinationals were found to be doing just this, e.g. the C&P Innovation Program at Monash University, where the centre had training programs for SMEs run by multinationals and dedicated networking events for centre participants focused on enabling business-to-business (B2B) and business-to-consumer (B2C) collaboration. These are important considerations for an IA centre operating in ANZ.

Engaging multinationals is imperative. However, it is noted that the ones with R&D operations had very different needs to those with non-R&D operations in ANZ. The key for a centre is to present a value proposition that appeals to both types of multinationals, e.g. helping a non-R&D multinational showcase its product capability while linking into their global R&D units, as Monash University has done with PerkinElmer with the establishment of the PerkinElmer Flagship, linking to global R&D units in Malaysia, China and the USA. A multinational with some R&D activity in the country, on the other hand, will benefit with a deeper engagement in R&D while extending the collaboration globally to other R&D units, e.g. the world's largest chemical company,[54] BASF's membership of the C&P Innovation Program, which has linked Monash University to BASF India and BASF China.

Many of the IA collaborations observed within the ANZ universities strongly support a view that engaging with SMEs is not the same as engaging with larger companies or multinationals with or without R&D capability in ANZ, so different approaches are required for IA partnering in centres depending on the type of company.

Universities are able to value-add to companies in a partnership approach, e.g. a centre membership rather than ad hoc transactional projects. It is noted that small SMEs are best to access a centre via an industry association, with the industry association as the centre member. Medium SMEs and larger companies, including multinationals, should partner directly with centres as members of a consortium.

The main intent of a centre is to build a long-term pan-industry value chain, e.g. the C&P Innovation program had SMEs, multinationals and large Australian companies, as well as industry associations and government agencies, as members of the centre, representative of a global value chain for the chemicals and plastics industry. Similarly, the EPECentre membership consortium had members spanning the full electric power industry, from generation, transmission and distribution to contracting, manufacturing and professional services, as well as the peak industry association.

From an industry perspective, according to the Cooperative Research Centre Association (CRCA) Chief Executive, it takes time to collaborate with industry:

> (12 April 2016) Going to a company … with only a week or a month for them to make a decision on whether they support a particular proposal is not collaboration. Collaboration takes much more time and much more understanding of the strategic needs of the company or industry … it may take a year or two of discussion before a genuine collaboration is possible.[55]

[54] Source: http://cen.acs.org/articles/93/i30/Global-Top-50.html
[55] Source: http://us7.campaign-archive2.com/?u=5f89084f27654473fd36c00cb&id=3e7227a6e7

It is important for IA centre leaders and academic participants to understand that IA collaboration takes time. Last-minute approaches to industry collaboration, as described by the CRCA, not only put industry off working with universities, they can damage the reputations of centres and lead to the stereotyping of all universities in the eyes of industry, i.e. perception is reality. Psychologists call this a *schema*, referring to a mental representation of a group, object or situation; stereotyping is a type of schema (Atkinson, et al., 1953). This can have a long-term negative impact on the whole university community.

4.8.2 MODES OF INDUSTRY PARTICIPATION IN S&T CENTRES

Table 16 shows the modes of industry participation in centres and indicates whether they are CSR or commercially driven ($), in terms of the basic value proposition mode of participation in an IA centre. Note that the mode of industry participation in Table 16 influences the recommended business model for IA Centres in ANZ universities (Chapter 5).

Table 16. The mode of industry participation in S&T centres within ANZ.

Mode of Industry Participation **(CSR vs commercial ($) i.e. tax incentives?)**	**IA Collaboration Characteristic**	**Participation/Membership Implications**	**Examples of centres in ANZ universities**
a) Philanthropic (CSR)	CSR-aligned donation via a trust or foundation; donation viewed as equivalent to a membership, to achieve a public good outcome.	Contributes to the operation of a centre, with some membership benefits, e.g. concessions for conference fees. However, R&D and commercial activity are performed (independently) over and above the membership fee and are non-exclusive (open access for non-members).	EPECentre at the University of Canterbury.
b) Innovation capability ($)	Innovation capability service with access credits, i.e. unique skills for consulting and specialised equipment.	May be linked to co-investment required for a government grant, with discounted access rates for members; funds may or may not contribute to the operation of the centre; non-exclusive (open access for non-members), with consulting activity a strong feature.	A member version: Food Innovation Centre (FIC) at Monash University. A non-member version: Institute of Railway Technology (IRT) at Monash University.
c) Infrastructure ($)	Infrastructure with access credits (i.e. unique equipment or laboratory facility).	Typically linked to an industry co-investment required for a government grant, with discounted access rates for members; funds may or may not contribute to the operation of the centre; likely to be non-exclusive (open access for non-members).	MCN (Melbourne Centre for Nanofabrication) with multiple universities, including Monash University.

d) Co-location ($)	Co-location or embedded centre for a single company.	May be be linked to government co-investment; funds likely to contribute to the operation of the centre; exclusive to the company; typically orientated around a laboratory and some office space; R&D focused.	Axieo Innovation Centre at Monash University. Co-location is typically is a sub-category of R&D mode f) with elements of education and training, infrastructure and innovation capability access; this is the second most common form of IA centre behind R&D mode f).
e) Education and training (CSR)	Membership for training credits (professional development and upskilling or recruitment).	Funds may or may not contribute to the operation of the centre; typically involves workshops and seminars; participation in the centre may be exclusive for members; goal is skills development via the centre.	*None observed to date in ANZ, but feasible in theory. However, some centres encompass education and training, alongside research and industry, e.g. the EPECentre and the C&P Innovation Program.*
f) R&D ($)	Membership for R&D project credits.	Typically linked to industry co-investment required for a government grant; funds may or may not contribute to the operation of the centre; participation in the centre may be exclusive for members; goal is new IP co-creation via the centre.	The C&P Innovation Program and the BioPRIA *(with an incorporated ARC ITRH BAMI)* at Monash University. This is the most common type of S&T centre in ANZ universities
g) Sponsorship ($ or CSR)	Membership for a commercial purpose, sometimes CSR purpose.	For a specific commercial purpose, e.g. sponsorship for a new building or an annual conference; funds may contribute to the operation of the centre; participation in the centre may be exclusive for members.	*None observed to date in ANZ but feasible. Note: industry partners preferred to leverage tax incentives (e.g. R&D tax credit or rebate for charitable donations).*

The terms ‘industry collaboration’, ‘industry engagement’, ‘industry interaction’ and ‘industry partnership’ were interchangeably used within the university environment by many of the observed participants at the field-site ANZ universities. However, it is important to note that there is a practical distinction between these interchangeably used terms, which has been determined through the research. The term ‘industry collaboration’ is overarching. ‘Engagement’ and ‘interaction’ are the same, both referring to discrete touch points of activity, while ‘industry partnership’ refers to a collection of discrete engagements or interactions.

When a company is considered to be a member of an IA centre, it is in the realm of partnership, which in turn includes multiple engagements or interactions with this industry partner, i.e. member. A membership of a centre represents an overall collaboration between a company and a university. It also implies a deeper relationship between the company and the university. These distinctions are not prevalent in the literature on centres and few within universities understand the difference, which explains why these terms are used interchangeably, as shown in Figure 37, where 'collaboration' is the broad umbrella term and the scope narrows to 'partnership' (e.g. membership of a centre), followed by 'engagement or interaction' (ad hoc).

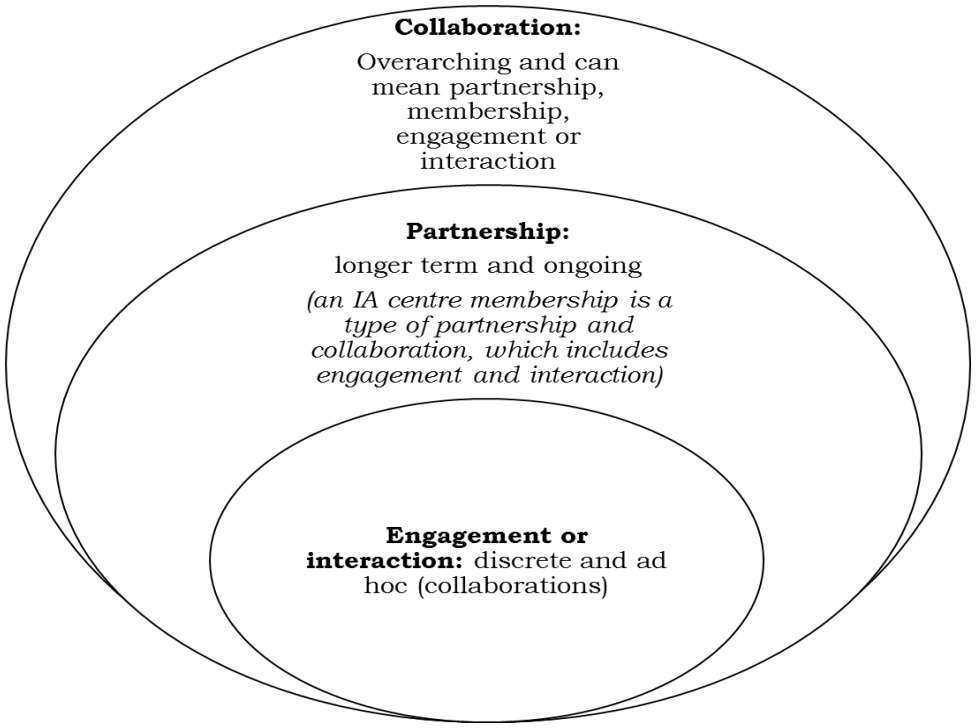


Figure 37 Defining the distinctions between IA collaboration, partnership/membership and interaction/engagement, based on the research findings.

4.8.3 MEMBERSHIP CONSORTIUMS FOR CENTRES

S&T centres that were described positively by university participants, industry and government alike were the ones that had an end-user fee-paying membership consortium model. These centres had end-user industry as members of a consortium, along with a strong governance structure via an industry-chaired end-user IAB. These centres included the EPECentre, C&P Innovation Program, Australian Power Quality and Reliability Centre (APQRC) and Bioresource Processing Research Institute of Australia (BioPRIA). For example:

> The EPECentre stated (30 September 2010) in a press release, 'We have been described as being an exemplar for our research collaborations and relationships with industry. We meet the needs of the industry and our graduates get the relevant and required skills. Other countries in the world look to us to try and replicate our successful model, having over 35 industry partners and a network of more than 700 industry contacts' .[56]

[56] Source: http://www.comsdev.canterbury.ac.nz/chronicle/2010/ChronVol45-15.pdf

Some notable international examples from outside ANZ include the QUILL (Queen's University Ionic Liquid Laboratories) in Ireland and the Centre for Sustainable Chemical Technologies at the University of Bath in the UK.

Table 17 summarises S&T centres that were observed in ANZ with end-user membership consortiums, including several international examples.

Table 17 Identified S&T centres in universities with end-user membership consortiums, including international examples.

S&T centres in universities with end-user membership consortiums
Electric Power Engineering Centre (EPECentre), University of Canterbury, NZ Established in 2002, the EPECentre is NZ's Centre of Excellence for electric power engineering, with significant industry support from its end-user members via a charitable trust membership (Power Engineering Excellence Trust (PEET)) and an end-user IAB with many alumni.[57] The EPECentre's membership consortium is sector wide (power generation, transmission, distribution, manufacturing, consulting, contracting, education and research) and enables opportunities for the industry to work together to co-invest and solve industry-wide challenges, e.g. graduates entering industry, security of electricity supply, new technology, integration of renewables.
Australian Power Quality and Reliability Centre (APQRC), University of Wollongong, Australia Established in 1996 as the Integral Energy Power Quality and Reliability Centre (IEPQRC), it reinvented itself in 2015 into a membership model with multiple members, after starting out as a single-industry member centre, i.e. Integral Energy. The centre was renamed the Australian Power Quality and Reliably Centre (APQRC) and also has an end-user IAB.[58] What this demonstrates is a transition model from a single-member to a multiple-member membership consortium.
Centre for Advanced Engineering (CAE), University of Canterbury, NZ The CAE had a membership model via donations to a charitable trust with an end-user IAB. However, the Centre closed after 25 years of operation in 2015.[59] This is an example of a sustainable S&T centre model that added value for as long as it was needed by the industry members. It served its purpose and closed once the mission was accomplished.

[57] Source: http://www.epecentre.ac.nz/
[58] Source: http://www.elec.uow.edu.au/apqrc/
[59] Source: www.cae.co.nz

Chemicals & Plastics Manufacturing Innovation Network and Training Program (C&P Innovation Program), Monash University

The C&P Innovation Program is a partnership with PACIA (Plastics and Chemicals Industries Association) and the chemicals and plastics industries. It was in established 2015 and is co-funded by the Victorian State Government of Australia. Inspired by the EPECentre in NZ, it has more than 20 industry members including SMEs, large Australian companies and multinationals, as well as industry associations and research institutions, representing the whole supply chain. It also has an end-user IAB and a unique co-director leadership model with a dedicated manager. The goal of the centre is to create global market opportunities, increase collaboration, enhance manufacturing and deliver a new generation of industry professionals. It involves over 50 researchers, engages academic staff from across science and engineering (chemistry, chemical engineering and materials engineering), has an inaugural cohort of 17 PhD students and aims to undertake 60 training initiatives with industry within its first 3 years of operation. The centre has also paved the way to spawn new strategic initiatives with members, such as the Axieo Centre for Innovation and the PerkinElmer Flagship Facility.[60]

Centre for Sustainable Chemical Technologies, University of Bath, UK [INTERNATIONAL EXAMPLE]

The Centre, established in 2008, places fundamental concepts of sustainability at the core of research, training and outreach in applied chemical sciences. A range of industry partners is involved in the Centre. Industry participation includes partnering on PhD research (science or engineering), strategic advice, internships, training and events (e.g. summer showcases). The Centre is co-funded by the government's EPSRC (Engineering and Physical Sciences Research Council) and has an IAB drawn from its end-user members.[61] This Centre is somewhat akin to the C&P program in Australia, evidence that similar models may also work in the UK.

Dow Centre for Sustainable Engineering Innovation, University of Queensland, Australia

The Centre was established in 2015 and is funded by a donation from the multinational company Dow Chemical, as its sole industry member. The Centre was championed by the CEO of Dow, an alumnus of the University of Queensland (UQ), who maintained a strong relationship with UQ. He was awarded an honorary UQ doctorate and was named UQ Alumnus of the Year in 2005.[62] At the launch of the Centre, the CEO of Dow indicated in a video interview (on the UQ website) that the decision for the Centre was made by Dow after spending 5–6 years identifying key researchers to work with in chemical engineering.[63] This is an example of a multinational building a centre with an ANZ university. It also demonstrates the power of alumni relationships for centres.

[60] Source: https://www.monash.edu/cpmin

[61] Source: http://www.bath.ac.uk/csct/cdt/

[62] Source: https://en.wikipedia.org/wiki/Andrew_N._Liveris

[63] Source: https://northamerica.uq.edu.au/news_posts/dow-centre-opens-at-uq/

Axieo Centre for Innovation, Monash University, Australia

This Centre was established in 2015 and funded by new Australian company Axieo, as its sole industry member. The concept of the Centre was championed by the CEO of Axieo, an alumnus of Monash University. The Centre's scope includes partnering on research projects, training and internships. The Centre links to Axieo's membership of the C&P Innovation Program, also at Monash. Axieo's Centre is hosted within Monash University's state-of-the-art Green Chemical Futures building, enabling greater access to academic capability (science, engineering, business) and collaboration, and research infrastructure. This gives Axieo a point of differentiation and a competitive edge in the global industry setting.[64] This is an example of an entrepreneurial ANZ-owned company partnered with a university for a centre, spawned as a result of the relationship developed between Axieo and Monash for the C&P Innovation Program.

Queen's University Ionic Liquid Laboratories (QUILL), Queens University, Ireland [INTERNATIONAL EXAMPLE]

An international example of a membership model S&T centre is QUILL in Ireland at Queen's University. It is found to have 14 industry consortium members on the QUILL website (as at 2016) and members are noted to contribute *(Nature,* Volume 400, 19 August 1999; pages 797–799) up to US$32,000 each per year for membership.

Bioresource Processing Institute of Australia (BioPRIA), Monash University, Australia

BioPRIA is focused on creating new industries and transforming established ones through education and research. BioPRIA incorporates the ARC ITRH Bioprocessing Advanced Manufacturing Initiative (BAMI) and was formerly known as the Australian Pulp and Paper Institute (APPI) at Monash University. It was originally established in 1989. It is led by an experienced centre director.[65] This centre has found ways reinvent itself and move with the times by creating value for industry, led by an serial intrapreneurial centre director and with an end-user led IAB and membership consortium, similar to the EPECentre.

Some S&T centres focused on industry were also found to have alternative membership consortiums without end-user members per se or membership fees. These centres typically had participating universities, research institutions, peak industry bodies and other relevant government entities funded by a strategic government grant, e.g. the Victorian Centre for Sustainable Chemical Manufacturing (VCSCM) with Monash University, CSIRO, EPA Victoria and the Plastics and Chemicals Industries Association (PACIA). Nevertheless, these consortiums were set up to support end-user engagement and enabled relationship building with end-users, although end-users were not directly members themselves.

Several centres without a membership consortium were observed to excel at end-user industry engagement, such as the Institute of Railway Technology (IRT) at Monash University. The IRT evolved out of BHP Billiton and was moved to Monash University in 2000 along with its key employees. It has an industry-professor centre director who transferred from BHP with the centre to Monash. The IRT continues to perform ongoing services for BHP, as well as working for other companies independent of BHP. The IRT's brochure indicates that it has 7 core staff members (including a director, an

[64] Source: http://www.axieo.com/corporate/news-and-views
[65] Source: http://www.biopria.com.au/

associate director and a research manager) and has provided technical support to over 90 companies within the railway sector, locally and internationally.[66] It is one of the top industry-engaged centres within the university and has won awards for its collaborative projects with industry, including the Best Research and Development Collaboration Award from the Business Higher Education Round Table (B/HERT) in 2015.[67]

The IRT is an example of a centre without a membership consortium that has a strong value proposition to industry around its specific capability offering, i.e. a-fee- for- service model, identified previously as an I*A centre (Table 12). A centre director of an I*A centre is required to have trusted industry relationships and strong business development (BD) skills to ensure ongoing revenue for the centre. An I*A centre's success is heavily dependent on the BD capability of the leadership team to compensate for the uncertainty in cash flow, i.e. it is dependent on consulting and research grant income, through not having a membership model to underwrite and fund core operations and staff salaries. Anecdotally, the success of an I*A centre may also depend on whether it was industry spawned and then transferred to a university, thus having common roots with industry, which in turn strengthens its connection to the industry it serves. However, this needs to be explored through future research.

The industry relationships for an I*A centre will likely be at a technical management level, rather than at C-level[68] (i.e. senior executive level in industry), because of the nature of the offering, i.e. fee-for-service technical consulting and applied research. This is instead of a broader strategic collaboration that would likely engage the C-level executives of companies, with activity spanning research, education and industry interaction. This is evidenced by the fact that the IRT does not have an IAB. Also, having a dedicated (fulltime) industry-professor centre director makes this centre feasible. Background findings suggest that C-level executives in ANZ are also more likely to be interested in innovation strategy and training than are the next tier of management (e.g. technical managers), who are focused on operations (subsection 1.2.3).

Usually centre directors are academics who have fulltime day jobs and perform the centre director role as a secondary duty. The Food Innovation Centre (FIC) at Monash had a similar starting point to the IRT, with a centre director who is an industry professor, but aims to build a membership consortium and an IAB, according to the business model proposed (Chapter 5) in 2016. There is a strong likelihood that an I*A may not be viable if it does not evolve from industry and have the industry-professor type of leadership. Hence, this is not the norm for the majority of centres, which are university spawned with academic centre directors. An I*A is an interesting variant of IA centres that has scope for future research, but has been taken into consideration for the recommended ANZ business model (Chapter 5).

It is noted through the EPECentre and the C&P Innovation Program that as early adopters signed up as members, championed by key individuals typically at executive levels (some of them alumni), the credibility of having these early adopters as members helped these centres engage potential new members on an ongoing basis. Furthermore, it has been seen that positions on the IAB can be offered to key industry executives (at C-level) who volunteer for the role, as a part of the strategic partnering process with selected industry members that could lead the membership consortium by example. This is a key element of the recommended business model (Chapter 5).

There is a momentum that builds when it comes to companies agreeing to a centre membership. Since the due diligence is completed by the early adopters, the credibility of those companies and the IAB can create a snowball effect for potential members, to the point where a company will look

[66] Source: https://platforms.monash.edu/irt/images/stories/irt-brochure.pdf
[67] Source: http://www.bhert.com/award-winners.html
[68] Source: https://hbr.org/2014/03/the-seven-skills-you-need-to-thrive-in-the-c-suite/

at a centre and think 'Why are we not a part of this when everyone else is?' This has been observed in practice at the field-site universities with the EPECentre and the C&P Innovation Network. Regardless, the value proposition, i.e. the pitch, is required to be compelling for the snowball effect to come to fruition, e.g. the opportunity to meet a company's criteria for CSR and derive commercial benefit through R&D. A key component of the value proposition to industry members is the span of activity on offer through a centre. An activity portfolio that spans research, education and industry interaction (section 4.9) has the ability to meet members' needs in equilibrium (balance) between CSR and commercial R&D. This is another important aspect of the recommended model for ANZ (Chapter 5).

Building trusted relationships with member company representatives has emerged as a key ingredient, e.g. when a CEO changes, the value proposition for centre membership often has to be re-pitched. Therefore, the EPECentre had multiple points of contact within a single member company, often at the senior executive level, in addition to several relationships at the technical operations or R&D management level. The EPECentre was also observed to actively keep in contact with its alumni, i.e. former EPECentre scholarship recipients who were pursuing careers in industry. It is also noted that many of the first alumni were reaching mid-level management positions within companies, thereby creating a significant support pool (a generation of alumni) within the industry for the EPECentre.

When alumni become decision-makers in industry, there is a higher likelihood of support for the centre from those companies, especially if the centre or the university has helped those individuals along the way, while they were university postgraduate or undergraduate students. The Dow Centre for Sustainable Engineering Innovation, established at the University of Queensland in Australia, is an excellent example of alumni support, where the US-based global CEO of Dow Chemical is an alumnus of the University. The Dow Centre was launched with an AUD$10 million donation from Dow Chemical under the stewardship of the Dow CEO. This aligns with the view that alumni are the leading philanthropic supporters of a university (section 1.2).

4.8.4 PERIOD AND TYPES OF CENTRE MEMBERSHIP FUNDING

The types of membership funding for S&T centres across the observed field-site ANZ universities have been found to consist of one or more of the following:

- One-off (no further contributions), annual contributions (negotiable each year) or multi-year commitments (3–5 years)
- Funding provided as charitable donations (from a company to a trust/foundation set up for the centre) or research contributions (cash and in-kind support usually linked to a government grant requiring industry co-funding)
- Fixed-rate membership (i.e. all members contribute the same level of funding) or tiered levels of membership (proportional to the desired level of partnership with the centre); much of this is driven by the type and size of a company, e.g. a multinational versus an SME.

4.8.5 VALUE PROPOSITION FOR INDUSTRY MEMBERS OF CENTRES

Table 18 provides several examples of what is typically offered to industry as a value proposition for centre membership, drawing on two different S&T centres in ANZ, the EPECentre (35 members in 2011) and the C&P Innovation Program (20 members in 2015), respectively.

During the field observations at the three field-site ANZ universities, it was recognised that SMEs may struggle to join a membership model in terms of cost and resources available. However, to overcome this, centres such as the C&P Innovation Program have invited industry associations that have SME members to become in-kind members of the centre, which enables on-demand participation of SMEs of all sizes to engage with the centre. This is a bespoke approach that is suited to the ANZ

environment, where over 99% of firms are SMEs (section 1.2). This is a key finding for the recommended business model (Chapter 5).

Table 18 Summary of centre membership benefits and fees.

Centre membership	Benefits to industry members	Level of membership funding
Electric Power Engineering Centre (EPECentre) via membership donations to the Power Engineering Excellence Trust (PEET) at the University of Canterbury, NZ	▪ Acknowledgement of membership in marketing collateral including the distribution of company marketing material at appropriate EPECentre educational, research and industry events and website. ▪ Involvement of company sites for annual EPECentre field trips, to promote company to students. ▪ Exhibition space at EPECentre events. ▪ Participation and discounts at professional development, such as seminars, conferences and workshops. ▪ Invitations to participate in R&D projects for sector-wide benefit and discounted access to technical commercial services (i.e. consulting and testing). ▪ B2B networking across the pan-industry sector members (i.e. electricity generation, transmission, distribution, consulting, contracting, peak bodies, research and education). ▪ Potential tax incentives (charitable donation) for contributions made. ▪ Voting rights for the IAB, depending on level of membership. ▪ Priority access to high-quality graduates and interns via the EPECentre ▪ Relationship-building with key academic researchers of interest to the industry member. <u>Note:</u> membership contributions to the trust excluded research or commercial projects for members, given the charitable status of the trust. Funding for research and commercial projects with the EPECentre were independent of trust membership.	Annual payments (renewable each year): ▪ Ordinary membership: NZ$5000–19,999 ▪ Premium membership: NZ$20,000+ per annum ▪ In-kind membership (recognised as Centre supporters) for research institutions and some professional bodies.
C&P Innovation Program (government co-funded) at Monash University, Australia	▪ Sponsorship of an R&D innovation PhD project (commercial in confidence for each member) for the member company , where a company can nominate the project topic, provide ongoing direction, access a free licence to the IP for commercialisation with a negotiated royalty back to the university, recognising background IP contribution from project participants including academic supervisors. ▪ Relationship-building with academic researchers working in areas of interest to the company. ▪ Option to select and recruit high-quality PhD students assigned to projects via the centre, including 3-month internships to test out the PhD student. ▪ Participation in training initiatives (innovation management, business management and advanced technical applications). ▪ Attendance at showcasing events. ▪ Acknowledgement of membership in marketing collateral ▪ Industry networking, B2B, across the global value chain, with members ranging from SMEs to large Australian companies, multinationals and industry associations. ▪ Potential tax incentives (R&D tax credit) for contributions made. ▪ Recognition on marketing collateral at centre events and website.	Fixed membership fee for 3 years: ▪ Based on $12,500 per annum per PhD project (as a unit of measure) for those members with projects, plus in-kind support for the centre. ▪ $5000 per annum for other members, plus in-kind support for the centre. ▪ In-kind membership (recognised as centre supporters) for research institutions and some professional bodies. Given that it was co-funded by government, there was a minimum industry co-contribution requirement of over 3 years to match the government co-funding over 3

	▪ Note: some nominated member company representatives were appointed to the IAB by Monash University, with government endorsement; the C&P Innovation Program inspired by the EPECentre in NZ.[69]	years; anything over above this level was at the discretion of the centre.

4.8.6 FUNDING MODELS

From the EPECentre case study, it is noted that the centre membership funding received for operating the centre was separated from other revenue sources generated by the centre, such as R&D (including, consulting and research funding). The EPECentre funding model consisted of four independent streams of income: (1) funding received from the membership consortium; (2) R&D; (3) other commercial activities, e.g. revenue from conferences and workshops; and (4) internal transfers from within the host university for services performed, e.g. teaching services provided by the EPECentre to the host department.

The key funding enabler was the membership funding, which funded the core operations of the centre, including education programs (e.g. EPECentre undergraduate and postgraduate scholarships) and the salary of the centre director or manager. This allowed for the steady employment of a centre director or manager to oversee the centre, and drove opportunities for further revenue generation from other sources, i.e. revenue sources (2), (3) and (4) as stated above, as well as attracting new members for the centre.

The membership funding also underpinned the salary of the hybrid academics (research engineers), on the rationale that each calendar year the EPECentre was expected to generate revenues from sources (2), (3) and (4) to cover all costs where possible, while the membership funding source (1) provided an underwritten guarantee to the host university to keep the centre not-for-loss, i.e. a net financial position at the end of the year that was cost neutral. These financial arrangements were part of the hosting arrangements written into the MoU between the EPECentre and the host department (section 4.2).

The MoU was not legally binding, but there was mutual respect between the industry partners on the IAB and the university to abide by it. It certainly carried reputational risk to all parties if the MoU (section 4.2) was breached, regardless of any legal liability, as previously discussed under host arrangements sections. Arrangements for the MoU were reinforced by the involvement of key industry stakeholders and university executives on the EPECentre's IAB. This enabled the centre director to pursue intrapreneurial strategic initiatives (subsection 4.5.5) underwritten by the centre's membership consortium, e.g. the commencement of its R&D program in 2005 with the recruitment of hybrid academics (Lawrence & Bodger, 2005) and the publishing of the EPECentre Book Series in 2008.[70] The robustness of this financial model meant that funding allocations from the membership (1) were often not fully required to be spent, because the centre was able to generate sufficient revenue from alternative sources (2), (3) and (4) to cover its expenditure.

Herein is demonstrated a robust, self-sustaining funding model for an S&T centre in ANZ that does not rely on one revenue source alone and is able to do so without core government funding. The membership fund provides crucial financial underpinning for the centre to keep operating, as long as the industry is engaged and the university is supportive. The financial approach of the EPECentre is a key finding for the recommended business model for ANZ (Chapter 5). Ultimately, the self-sustainability of a centre is about creating value-adding for stakeholders and generating impact in the KE (section 2.3) through its activities.

[69] Source: https://docs.education.gov.au/documents/case-studies-university-business-collaboration
[70] Source: http://epecentre.ac.nz/books/index.shtml

4.9 PORTFOLIO OF CENTRE ACTIVITIES FOR KNOWLEDGE ECONOMY IMPACT

The portfolio of activity adopted by a centre determines the KE impact of the centre. A centre portfolio of activity spanning research (R), education (E) and industry interaction (I), referred to as REI activity, is held in equilibrium to value-add to industry, university and government stakeholders alike. The purpose is to deliver outcomes through a centre that will have social and economic value to ANZ, such as the creation of highly skilled jobs, i.e. graduates (knowledge workers) and commercial investments derived through R&D, which in combination lead to a nation's prosperity and advancement in the KE (section 2.1).

4.9.1 PORTFOLIO OF ACTIVITIES

The data collected under this theme from across the field-site universities over 2005–2016 presents a portfolio of activities for centres across the three pillars of: (1) research; (2) education; and (3) industry interaction. This is summarised in Table 19 based on observations of S&T centres across ANZ made by the researcher as a participating observer undertaking insider-led research. The REI activities indicated in Table 19 have been fed into the recommended business model for an ANZ centre (Chapter 5).

Table 19 Portfolio of activities for S&T centres described based on observations of S&T centres at the field site ANZ universities and the EPECentre case study.

RESEARCH (INCLUDING RESEARCH AND INNOVATION):

- **Research & Development:** industry research contracts, research grants, consulting for industry, prototype development, experimental projects (entrepreneurial, e.g. EPECentre R&D work with smart LED lighting technology[71]), professional R&D project and program management (e.g. EPECentre manager as project manager on all contracts), R&D demonstrations (e.g. EPECentre's demonstrations with Lighting Arc Drawing research[72]), partnering on large programs with industry (e.g. EPECentre's 3-year Ministry of Science and Innovation (MSI) and Electricity Engineers' Association (EEA) funded project to produce a Power Quality Guide for NZ[73]), hosting and secondments with industry (e.g. R&D internships for PhD students of the C&P Innovation Program), shared infrastructure (e.g. C&P Innovation Network researchers using facilities in the state-of-the-art Green Chemical Futures (GCF) building at Monash University;[74] EPECentre researchers utilising and supporting (including upgrading laboratories with industry support[75]) the High Voltage Laboratory, Power Electronics Laboratory and Electric Machines Laboratory at the University of Canterbury).
- **Research publication:** journals and conferences (e.g. EPECentre University of Canterbury conference publications at annual EEA conference, winning numerous Best Paper Awards for generating knowledge impact for the industry in NZ[76]).
- **Technology transfer:** commercialisation (patenting, licencing, IP assignments, joint ventures, start-ups and spin-outs (e.g. ARC Centre of Excellence for Electromaterials Science (ACES) with spin-out company AquaHydrex via Monash University and the University of Wollongong[77]).
- **PhD projects** with scholarships provided by the centre and co-supervision by centre staff (e.g. EPECentre PhD scholarships).[78]
- **R&D showcases** (e.g. EPECentre's annual R&D Expo, which typically attracted hundreds of participants, and included live R&D demonstrations, scholarship awards ceremony, keynote addresses by industry CEOs and media coverage)[79].
- **R&D project teams** including **hybrid academics** (centre research staff), student casuals (**research assistants**), **consultants**, **postdocs** and **research associates** (academic staff of the university).

[71] Source: http://www.epecentre.ac.nz/research/past_research.shtml
[72] Source: http://www.engf.canterbury.ac.nz/pubs/EPECentre%20RD%20Expo%20details.pdf
[73] Source: http://www.eea.co.nz/tools/products/details.aspx?SECT=publications&ITEM=2577
[74] Source: https://www.monash.edu/cpmin/about-us/location
[75] Source: http://www.comsdev.canterbury.ac.nz/news/2005/050907a.shtml
[76] Source: http://www.eea.co.nz/Site/about/awards/Conference-Awards-Winners.aspx
[77] Source: http://monash.edu/news/show/aquahydrex-company-a-commercial-first
[78] Source: http://www.epecentre.ac.nz/students/scholarships.shtml
[79] Source: https://www.youtube.com/watch?v=9DOsKro3OqI and https://www.youtube.com/watch?v=SXj6y68TNaI

- **Research advisory committee** involving core academic research group associated with the centre and research collaborators from other organisations (where appropriate).

EDUCATION (INCLUDING EDUCATION & TRAINING):

- **Annual scholarships and prizes:** industry-funded scholarships and prizes for undergraduate or postgraduate students.
- **Hosting of students scholars within the centre:** recognised as a part of the centre's team (including undergraduates and postgraduate students); **student scholars**: EPECentre **scholarship recipients** received mentoring by staff, access to facilities (meeting rooms, labs) and hosting within industry-style office space for scholars alongside staff.[80]
- **Mentoring and professional development training**: C&P Innovation Program provides mentoring and professional training (business, innovation and advanced technical topics) for its PhD scholars (inaugural cohort of 17 PhD postgraduates), as well providing them with scholarships and coordinating internships.[81]
- **STEM outreach:** primary and secondary schools; EPECentre examples: support for TVNZ Kids Fest Sparks n' Arcs, EPECentre DVD sent to all secondary schools in NZ (pre-YouTube era), Energise Your Future Challenge – nationwide school competitions engaging all secondary schools in NZ, promote careers pathways through posters and advertising (e.g. EPECentre cinema adverts on power engineering careers).
- **Supervision by centre staff:** co-supervision of undergraduate and postgraduate student projects e.g. PhDs.
- **Improving quality and quantity of graduates:** this links to scholarships, contributions to courses, upgrades to lab infrastructure (used by students), scholarships, mentoring, career planning, industry exposure, internships, etc.
- **Lecturing and tutoring by centre staff:** undergraduate and postgraduate classes, tutorials and labs.
- **Work placement (internships) and graduate recruitment:** for undergraduate and postgraduate students.
- **Participation in academic conferences and workshops:** for centre staff, research associates and students.
- **Joint academic publications:** centre staff and university academic staff.

INDUSTRY INTERACTION (FOR EDUCATION AND RESEARCH):

- **Active industry relationship management;** communicating with members, partners, research collaborators, e.g. invitations to events, notifications, e-bulletin, discounts for events, including a database of industry contacts (e.g. by 2011 EPECentre had 35 industry members and over 700+ industry contacts (including senior executives, technical managers, human resource managers and recent graduates).
- **Knowledge Exchange:** consulting and testing services (e.g. EPECentre's specialised consulting services for industry with hybrid academic centre staff and academic research associates of the university[82]), independent opinions, industry guidelines (e.g. EPECentre's publication "'Guide to Power Transformer Specification Issues" in 2009 is used by industry practitioners internationally[83]), hosting of IA workshops and international conferences (e.g. EPECentre's hosting of Australasian Universities Power Engineering Conference (AUPEC) in 2009[84]), staff presenting at national and international conferences, joint publications with industry, technical book publishing (e.g. EPECentre's Book Series with publications such as the GREEN book on renewable energy integration in 2008[85]), invited talks, public seminars (e.g. EPECentre Seminar Series), thought leadership interviews, use of social media (e.g. LinkedIn, Facebook, Twitter and YouTube), magazine articles and press releases.
- **Joint workshops and conferences with industry:** hosting, organising and partnering.
- **Recruitment support:** promoting vacancies, filtering candidates, arranging interviews and mock interview training.
- **Donations to the university (via industry funding):** support research lab upgrades including sourcing research equipment, educational material, etc.
- **Press releases and magazine articles:** on topical issues for industry and university.
- **Industry input into curriculum:** undergraduate and postgraduate courses.
- **Special visitors via the centre:** one-off guest lectures, public seminars, visiting lecturers for course modules.
- **Publications for industry**: technical papers, technical guidelines, technical resource books (i.e. knowledge transfer).
- **Careers events**: e.g. EPECentre Convention (focused careers event for power industry with industry speakers and trade exhibits, annually since 2002).
- **Annual reports and electronic newsletters (e-bulletin):** to inform stakeholders including industry members, research partners, students, university staff, government and community stakeholders.

[80] Source: http://www.epecentre.ac.nz/students/current_scholars.shtml
[81] Source: https://www.monash.edu/cpmin/PhD-researchers
[82] Source: http://www.epecentre.ac.nz/industry/services.shtml
[83] Source: http://www.epecentre.ac.nz/docs/research/guide_transformer_spec_issues.pdf
[84] Source: http://www.comsdev.canterbury.ac.nz/rss/news/?feed=news&articleId=79
[85] Source: http://epecentre.ac.nz/books/index.shtml

- **Industry showcasing events:** including hosting of networking events with keynote presentations by company CEOs.
- **Training and upskilling for industry:** professional education, e.g. workshops, courses, guidelines, reference books.
- **Road mapping for industry needs:** to address industry challenges including human capital and innovation (market-pull versus technology-push).
- **Partnering on large scale initiatives**: working to form consortiums to take on government co-funded grants.
- **Presenting investment opportunities to industry**: university IP/knowledge transfer.
- **Consulting to industry**: professional advice/opinion, technical assessments, technical troubleshooting and testing.
- **Alumni engagement**: keeping in touch with alumni networks (the next generation of decision-makers in industry).
- **Sponsorship of events**: e.g. EPECentre routinely sponsored the IET short paper event and the IYPT (International Young Physicists' Tournament).
- **Shopfront:** as a meeting places between university and industry partners, e.g. EPECentre premises opened in 2010.
- **Online engagement**: centre website and social media (LinkedIn, Facebook and YouTube).
- **Marketing material**: marketing collateral (including banners), capability brochures.
- **Participation at industry events:** conferences (including students, academics and centre staff), invited talks, panel representation and student volunteers for events.
- **Hosting Networking events with industry:** industry partners, university staff, government guests, students including B2B networking.
- **Secondments and exchanges with industry:** e.g. EPECentre with KEPRI (Korea Electric Power Research Institute).
- **Representation on strategic committees/boards for centre staff or associates:** national and international.
- **Hosting/embedding industry via the centre:** C&P Innovation Program supported Axieo staff embedded at the university (as long-term visitors) working at the Axieo Innovation Centre within Monash University.
- **Field trips to industry sites:** to showcase industry to students, e.g. EPECentre's North and South Island field trips to power industry sites with onsite talks and exclusive insight tours by industry engineers for students (30–40 per trip, accompanied by EPECentre staff and research associates).
- **Promoting ANZ cultural awareness:** e.g. EPECentre visits to Nukuhau Marae in Taupo to educate students on Māori culture in NZ, with respect to engagement with the electricity industry.

4.9.2 IMPACT FROM CENTRES

During an open-ended interview, one professor's eyes lit up at the thought that an entrepreneurial university meant recognising that the university now has three key missions (education, research, societal impact) instead of just two (education and research), i.e. research university transition to entrepreneurial university. This professor also concurred that a centre is an extension of the top capabilities of a university and the longer they last, the better the output. However, the professor stated that there is nothing out there to show universities, governments and industry what models for centres are workable for them to be self-sustaining. Furthermore, this professor firmly believed that the primary role a university can provide for industry is research training, and performing research is about setting up a training environment.

As a world-leading academic, this professor described his passion for research and science and their significance and purpose to society. He saw translating (transferring) the work he did to industry as a meaningful societal benefit. He gave an example of an SME that he was collaborating with to develop alternative products for hospitals and public services, and possibly even for homes. As a philosophy, he firmly believed that helping industry would benefit the country and his graduates. Hence, despite the stereotypes of ivory tower universities (section 2.3), many leading academics believe in contributing to society by engaging with industry. They see it as a win–win for the country and for their students.

Companies from many non-electricity industries also engaged with the EPECentre for its R&D capability, e.g. the EPECentre export joule log heating program with STIMBR (Stakeholders in Methyl Bromide Reduction) for the NZ forestry sector, with the program led by the lead research engineer

(a hybrid academic) of the EPECentre.[86] The EPECentre did not limit engagement to just industry consortium members and had an open-access policy for non-members to utilise its R&D capability. This is another key characteristic for the recommended ANZ business model (Chapter 5).

As a means of becoming a sustainable enterprise and being informed by the research, the EPECentre did not limit its industry engagement activities to just PEET members, exclusively. This in turn created spill-over benefits to other industrial sectors and society in general, i.e. KE impact. The EPECentre recognised the need to contribute to its community. It also actively recognised the direct links between the schools sector, the tertiary sector, future industry leaders and research talent. Hence, the centre supported outreach activity into schools, e.g. EPECentre's Energise Your Future Challenge for all NZ secondary schools.[87] This was part of the REI activity that enabled a value proposition to members that spanned commercial R&D and CSR. The EPECentre was also actively involved in marketing education at the University of Canterbury and either directly or indirectly initiated up to 20 premium scholarships per year. Consequently, the EPECentre morphed into one of the most active entities within the University of Canterbury by 2010 for offering premium scholarships that were completely industry-funded.

The EPECentre case study shows that it had strong working relationships with peak industry associations such as the NZ Electricity Engineers' Association (EEA) and also via professional engineering entities such as the Institute of Electrical and Electronic Engineers (IEEE), the Institution of Engineering and Technology (IET) and the International Council on Large Electric Systems (CIGRÉ). Also, the EPECentre interacted with the Australian Power Institute (API), which was established in 2007 to support the Australian power industry.

There is a correlation between the establishment of the EPECentre in 2002 and the beginning of a rise in students enrolling in electric power engineering courses at the University of Canterbury. Furthermore, the number of power engineering graduates increased to 35–40 per annum by 2010. This equates to nearly three times the annual number of electric power graduates in the USA, per head of population measure, when compared to NZ through the University of Canterbury (Miller & Bodger, 2012).

Table 20 presents a selection of statements alluding to the impact and value that can be achieved for ANZ from IA collaborative S&T centres. These quotes have been extracted from press releases and articles pertaining to two of the observed ANZ S&T centres within the field-site ANZ universities, with portfolios in research, education and industry-interaction activities: (1) the EPECentre at the University of Canterbury established in 2002; and (2) the C&P Innovation Program at Monash University established in 2015.

Table 20 Selection of statements relating to impact from two of the sampled S&T centres in ANZ.

Statements and a graph relating to the impact of the EPECentre:
"You are not only providing the next generation of engineers but also, much more than that, you are providing the next generation of innovators." Hon Dr Wayne Mapp, the NZ Minister of Science, Research and Technology, 30 September 2010, in his keynote address at the opening of the new EPECentre premises and as a part of the EPECentre R&D Expo 2010 'Lightning ReStrike!'[87]  New Zealand Government Te Kāwanatanga o Aotearoa

[86] Source: http://www.stimbr.org.nz/about-us.html

[87] Source: http://www.comsdev.canterbury.ac.nz/rss/news/?feed=news&articleId=97

The EPECentre and Power Engineering Excellence Trust (PEET) Chair, Peter Berry stated (30 September 2010) that the EPECentre was created in 2002 by the University and industry partners to address the shortage of power engineers in the industry. It was also established to promote, support and enhance the education of engineers, and to develop a centre of excellence in power engineering research and innovation in NZ. He stated, "The tentacles of the EPECentre spread wide so for us to have a central focal point is critical for where we want to go in the future."[88]

In terms of the EPECentre's impact on producing power engineering graduates for NZ over 2002–2010 (Figure 38): "Within eight years we have almost trebled the numbers of students involved in power engineering. We have significantly grown postgraduate work and created a research group that is now recognised nationally and internationally for its innovation and leading research." Peter Berry, EPECentre Chair and PEET Chair, 30 September 2010[88]

POWER ENGINEERING EXCELLENCE TRUST

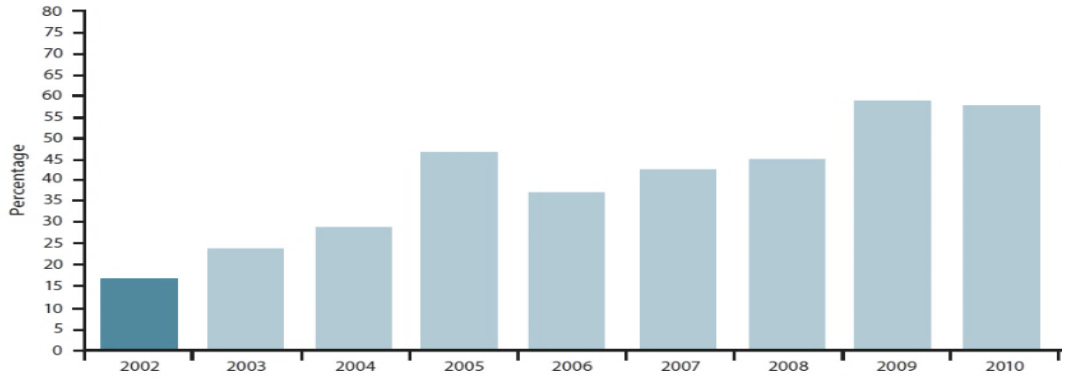


Figure 38 Power engineering graduates at the University of Canterbury 2002–2010, as a percentage of all electrical engineering graduates (adapted from: PEET Membership and Information Document).[89]

"For the last decade this has been the vehicle to inspire, encourage young students to take up electrical engineering courses and subsequently commence a career in electric power engineering. This was achieved through university–industry collaboration, an extensive number of student-based activities and scholarship programs which are now going to be expanded into secondary schools. This was a brand new model that had never been tested anywhere in the world and came without any guarantees." NZ Electricity Engineers' Association (EEA), 2014[90]

"The model worked and is now being used in other universities and disciplines around the world. The result for industry has been a good number of high-quality and well-educated graduates that are now contributing to the New Zealand electricity industry." NZ Electricity Engineers' Association (EEA), 2014[90]

eea Electricity Engineers' Association

Quotes and statements relating to the impact of the C&P Innovation Program:

"This exciting new initiative will act as a catalyst for new opportunities in global investment, innovation, productivity, job creation and economic growth." Hon Lily D'Ambrosio, Minister for Industry and the Minister for Energy and Resources, 3 June 2015, C&P Innovation Program launch at Monash University.[91]

"The Minister identified the pioneering nature of this initiative, in that it establishes a model that can be replicated across many industries and is scalable. It is an industry-aligned, structured approach for genuine industry R&D sector collaboration … welcomed the initiative that sees the best minds in academic

"Australian chemistry industry provides products and services that feed into 109 of 111 industry sectors, creating a multiplier effect in jobs and investment through Australian value chains … collaborative innovation in science and industry is key to driving manufacturing growth, improving products and processes and contributing to sustainable economic growth into the futures." Samantha Read, CEO of Plastics and Chemicals Industries Association (PACIA), 3 June 2015[91]

[88] Source: http://www.comsdev.canterbury.ac.nz/chronicle/2010/ChronVol45-15.pdf
[89] Source: http://www.epecentre.ac.nz/docs/membership/EPEC4199_PEET_Form_V3.pdf
[90] Source: http://www.eea.co.nz/Site/about/awards/meritorious-pat-bodger-bio.aspx
[91] Source: https://www.monash.edu/cpmin/Events/Chemicals-and-Plastics-Innovation-Network-launch

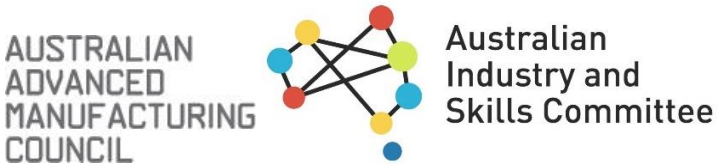
research joining forces with government and industry." Monash University, 3 June 2015[91]

"The initiative brings together multinationals, SMEs, PACIA and research organisations to create global market opportunities, increase collaboration, enhance manufacturing, and deliver a new generation of industry professionals." Monash University, 3 June 2015 [92]

"This sort of collaboration is vital to realising our vision of a manufacturing industry that secures long-term benefits for the economy, society and the environment while training the next generation of highly skilled workers and innovators." Samantha Read, CEO of Plastics and Chemicals Industries Association (PACIA), 3 June 2015[93]

"Your network is well ahead of the game in understanding how vital this is. Your work is also helping to power the rest of industry. New materials, new solutions and new applications are enabling manufacturers to remain competitive in a global context, and that is where your greatest impact is." John Pollaers, Chairman of Australian Advanced Manufacturing Council (AAMC) and Chair of Australian Industry and Skills Committee (AISC), 9 February 2016[94]

"One way to distinguish 'advanced' manufacturing is by the rate of technology adoption and creation, and the ability to use that technology to remain competitive and add value. That means thinking differently. It means, among many other things, thinking collaboratively. It means getting more PhDs into industry and ensuring our world-class research is developed and, crucially, that it is commercialised." John Pollaers, Chairman of Australian Advanced Manufacturing Council (AAMC) and Chair of Australian Industry and Skills Committee (AISC), 9 February 2016[94]



4.10 SUMMARY OF SYNTHESISED RESULTS FOR THE MODEL

KEY POINTS FOR FEEDING INTO THE CENTRE MODEL

ANZ is in transition from an industrial economy to a KE, with research universities becoming entrepreneurial universities. Hence, IA centres are becoming a vehicle for driving this change for ANZ universities in terms of KE impact, in partnership with industry. This is in line with the Triple Helix theory (section 2.2), which has provided the starting point for the theoretical underpinning of this research, stating that industry, university and government are the key ingredients for the KE, with universities playing a leading role.

The following sections provide key synthesised results and the final integrated grouping of findings for the business model (Table 21).

4.10.1 GROUPED SYNTHESISED RESULTS

Key findings from the totality of the analysed research are summarised. These have been categorised under five subheadings with respect to the development of the recommended business model for ANZ: [1] industry; [2] universities; [3] government; [4] centres; and [5] business models, as follows:

[1] Findings with respect to industry in ANZ:

- 99% of firms in ANZ are SMEs and only 1% are large or multinational enterprises (section 1.2). Hence, it is crucial that IA centres look to engage SMEs

[92] Source: http://monash.edu/news/show/network-launches-to-boost-australian-manufacturing
[93] Source: http://www.pacia.org.au/mediacentre/Celebrating-a-new-era-in-industry-and-research-collaboration_-_3-6-15
[94] Source: https://www.monash.edu/cpmin/Events/the-future-of-australian-manufacturing

- Leading ANZ academics demonstrate a willingness to support SMEs (section 4.8.1)
- SMEs look for support via short-term R&D projects: consulting, testing, development and applied research (4.8.1)
- For academics, the main constraint for working with industry is the lack of time available (4.1.2). Hence, hybrid academics via an IA centre can compensate, to undertake the short-term projects and to facilitate and resource IA R&D programs
- Furthermore, academic staff are able to utilise the 1/5 rule to allow them to consult for 20% of their time, which can be leveraged to provide guidance on industry R&D projects, managed by a centre and resourced by hybrid academics
- This requires the focus of IA centres to shift from research to R&D, which allows for consulting, development, technology transfer and research (basic, use-inspired, applied), i.e. to offer the full spectrum of the innovation continuum, ideally. This enables opportunities for engagement with SMEs, and partnership with medium and large companies (including medium SMEs, large ANZ firms and multinationals)
- Industry is becoming value-chain orientated globally (section 1.2). This requires IA centres to engage across the value chain and facilitate B2B and B2C collaboration for innovation
- In ANZ, executive-level management is interested in innovation and training, but the next tier down is not interested to the same extent. Hence, it is sensible for IA centres to ensure engagement at the executive level, especially on industry advisory boards (section 1.2)

[2] Findings with respect to government:

- 94% of ANZ universities are public, 47 out of the 50 ANZ universities (4.1.1), so the major stakeholder in ANZ universities is government
- A leveraging mechanism for government support (direct and/or indirect) for IA centres is crucial
- IA centre programs are in Australia only (ARC ITHR and ITTC)
- There are Australian CRCs also, but these are not university led and hosted per se (there are only 33 of them out of the 1600 estimated); they are R&D companies that are industry led; some are IA, but there is no accurate way of estimating the number
- NZ has no IA centre programs officially. Hence, there is scope to introduce an IA program in NZ
- ANZ both have strategic government programs that are one-offs, but these lack any sort of framework or business model
- There are 102 government-supported centres in ANZ. Hence 93% (1498) of ANZ university centres lack any formal framework or best practice guidance. This is the main target group that could benefit from the introduction of the recommended ANZ business model

[3] Findings with respect to universities:

- Universities in ANZ need to incorporate in their mission to help small SMEs convert to medium, and medium to convert to large ANZ firms or ANZ-owned multinationals. Centres are one of many mechanisms for achieving this, especially given the transition to the KE and ANZ's poor performance in the OECD on IA collaboration and research commercialisation
- ANZ universities are in transition to entrepreneurial universities, with the addition of the third mission of societal (social-economic) impact, in addition to the first and second missions of education and research, respectively.
- There is a lack of recognition of IA collaboration and team work in ANZ, e.g. awards for academic performance are for individuals and for research or education. However, some universities are introducing awards for societal impact (e.g. Monash, section 4.13), but not explicitly for IA collaboration or teamwork
- The government-driven ERA and PBRF metrics in Australia and NZ, respectively do not specifically address IA collaboration. These convert to block grant funding for ANZ's 50 public

universities, although the likes of ATSE are developing metrics to capture IA collaboration and influence government (4.3.1)

- In Australia, the block grant funding system favours Category 1 (competitive government grant funding for research) ahead of Category 3 (IA collaborative research). This in turn incentivises universities to focus on Category 1 ahead of Category 3 (subsection 4.2.3). Note: Consulting is not recognised as a valuable contribution to industry through the metrics and is frowned on (both in ANZ and overseas) in academic culture as a non-academic exercise (section 4.1.3), even though this is crucial for supporting SMEs (99% of industry) in ANZ by leveraging ANZ's significant research capability in universities, e.g. OECD statistics (section 1.2). This is contradictory to government calls for greater IA collaboration while incentivising the opposite behaviour in ANZ universities, which impacts on IA centres
- IA centre models need to transcend current government and university incentives and shift towards a more suitable model for ANZ that values IA collaboration and supports SMEs to be competitive in the impending KE
- Universities are also beginning to introduce industry professors or 'professors of practice'/para-academics (subsection 4.7.3) in a bid to improve IA collaboration. This is beneficial for IA centres and would be complementary to the introduction of hybrid academics to centres in parallel to undertake projects for industry and compensate for the lack of academic time and capability availability to perform IA R&D (section 4.7)

[4] Findings with respect to current centres in ANZ:

- The IAG Code developed through the research helps to categorise the various type of centres, including the focus groups for this research topic on university-based IA, i.e. IA and IAG centres (Figure 2)
- There are 1600 S&T centres out of a total estimated 5850 centres in ANZ universities, some of which are IA, IAG, but there is no accurate way of estimating the number. There are over 37,000 centres in the world, with 16% of the world's centres in ANZ universities (a high proportion)
- The 16% of the world's estimated number of research centres being in ANZ universities aligns with the OECD statistics that indicate ANZ has world-class research capability, underpinned by the 50 research-intensive research universities (subsection 4.1.1)
- Helping IA and IAG centres in ANZ would go a long way to improving the OECD stats for ANZ (section 1.2)
- Alumni in industry can be key connectors and/or champions for an IA centre; for example, Dow Centre for Sustainable Engineering Innovation at University of Queensland (championed by UQ alumnus, global CEO of Dow), Axieo Innovation Centre at Monash University (championed by Monash alumnus, CEO of Axieo), original industry board for EPECentre (included many alumni of the UC) (subsection 4.8.3; Table 15)
- Alumni are also known to be the leading source of philanthropic support for the university sector (section 1.2), e.g. evidence by Dow with UQ alumnus as global CEO, donated $10M to UQ to establish an IA Centre (Dow Centre for Sustainable Engineering Innovation)

[5] Findings with respect to business models:

- Business models are the framework (the 'what'), which underpins the strategy (the 'where'), which in turn leads to the implementation (business operations) of strategy (the 'how'). Currently, IA centres in ANZ universities do not have a business model framework, except for the funding rules for the 7% of government-funded centres in ANZ, nor is there an understanding of what is a recommended business model, which is what this research output provides

- Based on the findings, it is recommended that strategic plans for IA centres should be endorsed by their IABs and set for 3-year intervals (under the core banners of research, education and industry interaction, i.e. REI), followed by 12-monthly business plans for implementation
- Regardless, as the key driver for the business model, business strategy and business plan, the leadership and management that drive the organisation have a significant impact, i.e. they are charged with implementation and decision-making (subsection 2.16.2)

4.10.2 FINAL SYNTHESISED AND INTEGRATED RESEARCH FINDINGS FOR THE MODEL

The synthesised and integrated results for the recommended model are presented below (Table 21). These directly feed into the model development outlined in Chapter 5.

Table 21 The final synthesised key research findings for the recommended business model.

The final synthesised and integrated research findings for the recommended business model for IA centres in ANZ	
(1)	The foundation provided by the host department, including support arrangements within an MoU.
(2)	Executive reporting line within the university (e.g. dean or pro vice chancellor).
(3)	Membership consortium (paid end-user value-chain industry members and in-kind research collaborators and professional bodies). The membership funding is used to underwrite operations, including the funding of key centre staff, e.g. the centre manager or hybrid academics. Members are attracted to the value-adding provided from REI activity with tiered membership levels; they have strong relationships with the executive level in companies and many are likely to be alumni; companies latch on for CSR and/or commercial R&D reasons.
(4)	Access for industry members, host university academics (research associates) and students.
(5)	Centre leadership team: intrapreneurial serial innovators, a team of 2–3 people from a mix of: director and manager, plus co-directors, deputy-directors where appropriate; at least one of them is fulltime 1.0 FTE, i.e. one fulltime director or manager is 'dedicated' to the centre.
(6)	Industry Advisory Board (IAB): end-user executives, sometimes alumni, pan-industry and quasi-governance with university executive presence; meets 3–4 times per year and endorses strategic plan and business plans (full centre transparency, including finances, except for commercial-in-confidence R&D).
(7)	The centre's available budget, which includes revenue and expenditure, impacted by variable and fixed costs. ^Note: The combination of scope, time, budget and resources for the centre is viewed as the modified project management iron triangle, with resources in the middle of the triangle.
(8)	Industry end-user IAB chair (lead by example, heart of a volunteer, executive level and a representative from the end-user membership consortium).
(9)	The time available to conduct REI activities i.e. the portfolio of activities for the centre.
(10)	The scope of activities for the centre (REI activity); WTG gearbox is housed in the nacelle.^
(11)	Portfolio of activities (research, education, industry interaction): REI activity portfolios, each with programs/projects. REI is held in equilibrium, thus enabling value-adding for stakeholders from CSR through to R&D. ▪ R includes consulting, technology transfer, R&D (basic, use-inspired, applied), grants and contracts with hybrid academics who work to industry timescales (professionally project managed), publishing, research training ▪ E includes undergraduates, undergraduate/postgraduate projects, outreach, scholarships ▪ I includes professional development, training, (academic and industry) conferences/workshops, networking events, communications (social media and newsletters), secondments/exchanges, field trips, internships/jobs.
(12)	Professional project management of the portfolio and steering committees are paramount for projects and activities in REI.
(13)	Resources for the centre: centre staff and infrastructure (including access to labs and a shopfront), hybrid academics, industry/practice professors (translators), project managers, outreach, technicians and administrators (varies by size of centre), academics, postdocs and students, and subcontractors (research collaborators/consultants).
(14)	Access for non-members to utilise centre R&D capability: welcomes non-members to engage with the centre (i.e. not exclusive to members); this helps with project and funding opportunities, and to attract new members, to counter member attrition, as well as for SMEs.
(15)	Government core funding is typically 3–7 years in ANZ, which is therefore temporary.
(16)	The operating environment of the host university.
(17)	The academic underpinning research capability, gauged by ERA and PBRF metrics in ANZ.
(18)	The geo-political, socio-economic, techno-environmental conditions in ANZ, e.g. government policies.

(19	The centre's strategic plan (3 years, endorsed by IAB and stakeholders) and business plan (every 12 months, endorsed by IAB and progressively elaborated to deliver on strategy); they spin in the same direction.
(20)	The potential impact generated for the knowledge economy through the REI activity of the centre.

CHAPTER 5. THE RECOMMENDED CENTRE MODEL FOR ANZ

This chapter brings together the research findings and discussion presented previously (Chapter 4) in order to provide answers to the research questions and to accomplish the research objective of the project: provide a recommended business model for IA S&T collaborative centres within ANZ universities, This business model can be used as a framework for configuring new centres and for assessing the models of existing centres and problems which are unlikely to be perceived by the participants of centres, especially given that business model frameworks for centres are usually non-existent. As an extension to this research work, a preliminary set of multidimensional weighted indices (Decancq & Ana Lugo, 2013; Fernandes, et al., 2013) have been created and a weighted Centre Viability Index (CVI) has been suggested (Appendix D). The weighted CVI requires further investigation and is beyond the scope of this project, but does present the opportunity for future research.

5.1 RESEARCH QUESTIONS AND ANSWERS

5.1.1 WHAT IS A RECOMMENDED BUSINESS MODEL FOR IA CENTRES WITHIN ANZ UNIVERSITIES?

The key research question of determining a recommended business model for IA centres within ANZ universities has been answered. Section 5.2 onwards presents the recommended business model.

5.1.2 WHAT ARE THE TYPES OF IA S&T CENTRES WITHIN ANZ UNIVERSITIES?

The Venn diagram, named the IAG Code, identifies and codifies various types of research centres involving industry (I), academia (A) and government (G) (Chapter 1; Figure 2). The distribution of centres at the macro level is shown in Figure 39, which indicates various centre type combinations across the three domains of industry, academia and government. However, given the focus of this thesis on IA centres, the emphasis is exclusively on centres represented by the 'red stars', as these are university–industry partnered centres.

As presented in Chapter 1, the 'red stars' (Figure 39) refer to two types of IA centres in accordance with the IAG Code: (1) IA centres without direct (core) government funding (i.e. IA centres); and (2) IA centres with direct government core funding (i.e. IAG centres). Unless otherwise indicated, both of these are broadly referred to as IA centres throughout the thesis. There is also a variant of the IA type which is not shown in the diagram, referred to as I*A centres (Table 12), which identifies an industry-facing centre that is university-based but with a fee-for-service model for its core funding, i.e. implying that it is consulting and applied-research focused. Therefore, the types of IA S&T centres within ANZ universities are the IA and IAG ('red stars'), as shown in Figure 39, in addition to the I*A type.

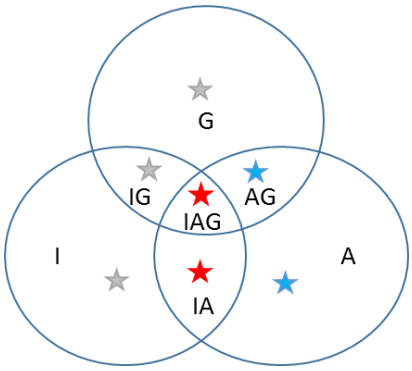


Figure 39 Distribution of research centres represented by colour-coded 'stars' across industry, academia and government; 'red stars' represent centres within a university that involve industry, while 'grey stars' and 'blue stars' do not.

5.1.3 HOW MANY S&T CENTRES ARE THERE IN ANZ UNIVERSITIES?

The number of S&T centres within ANZ universities (i.e. the market size for this research study) has been found to be approximately 1600 out of an estimated total of 5850 centres within ANZ universities (Table 9). This broadly represent the target markets for the recommended business model (the research output).

5.1.4 WHY ARE IA S&T CENTRES WITHIN ANZ UNIVERSITIES IMPORTANT TO ANZ?

ANZ is in transition to a KE and its situation is unique, as described previously (section 1.2), such as 99% of firms being SMEs, geographic isolation from the developed world, poor levels of collaboration between academia and industry, but with high-quality research capability in universities. Hence, there is an opportunity for IA S&T centres to be a vehicle of change and value-adding for the KE via entrepreneurial universities (section 2.3), taking into consideration that S&T is at the core of a KE (section 1.1).

The findings show that research (R), education (E) and industry interaction (I), i.e. REI activity, within an IA centre can lead to significant value-adding for stakeholders in industry, university and government (subsection 4.9.2). This goes back to the theory of the Triple Helix (section 2.2) that universities are the leading knowledge producers and industry is leading the knowledge consumer. Furthermore, IA centres are able to deliver more value to stakeholders by holding REI activity in equilibrium, thus being able to customise and serve the needs of a wider group of stakeholders, such as SMEs, by offering R&D capability that includes consulting as well more long-term research (section 4.9). The addition of hybrid academics as IA centre staff enables this to happen at industry pace (subsection 4.7.3) without imposing on the existing workloads of academic staff (i.e. a solution for reducing role strain; subsection 2.9.2) or relying heavily on postgraduate students or postdocs to deliver R&D projects for industry partners on short timeframes, which is the current mainstream approach in many S&T centres (sections 2.9 and 4.7). This takes into consideration that ANZ universities are in transition from research universities to entrepreneurial universities, as part of the ANZ transition to a KE (section 4).

The results also indicate that the value created for the KE goes beyond knowledge creation, because universities are also the producers (educators) of knowledge workers, i.e. graduates, an important role for IA centres. The REI activity also encourages industry to support IA centres not only in commercial R&D, but also to satisfy industry's CSR criteria (i.e. altruistic values), which overrides the traditional approach of focusing on R&D aspects, thus presenting industry with the option to support an IA centre for CSR, as well as for R&D (subsection 4.8.2).

The combined REI activity output from an IA centre in ANZ is able to drive innovation and value-add to industry, which converts to jobs, investments and export opportunities, i.e. social and economic impact in ANZ (subsection 4.9.2). The impact that can be achieved through IA collaboration is an area that is receiving considerable government attention in ANZ (Australian Government Chief Scientist, 2015; New Zealand Ministry of Business, Innovation & Employment, 2015; Australian Government Department of Industry, Innovation and Science, 2015a) and globally and there is a demand for improved models of collaboration (Bell, et al., 2015). Therefore, IA centres with viable business models are going to become increasingly important for ANZ.

In terms of centre sustainability, the findings indicate that, as long as an IA centre continues to add value to stakeholders and has an appropriate business model which includes research, education and industry interaction (REI) activity held in equilibrium (subsection 4.9.2), then the centre is well placed to achieve self-sustainability in terms of its framework. However, it is important to recognise that the business model is only the framework and it is not the only determinant of sustainability. The business model, together with the business strategy and the implementation of the strategy through the business plan (i.e. operations), must integrate with the centre's leadership team to achieve

overall self-sustainability. The business model is the 'what' (vehicle), the business strategy is the 'where' (the map) and the business plan is the 'how' (i.e. the implementation and operation) (2.16.2).

5.2 CONSTRUCTING THE MODEL

The synthesised parts of the recommended business model for an IA centre within ANZ universities (section 4.10.2) highlights the need for an integrated system that can bring together the various disparate components (Table 21), which takes into account the various complex (multidimensional) interrelationships of organisations and individuals involved in a centre, and the interdependencies of form and function. Therefore, the recommended business model is presented using a four-dimensional (4D) model that uses the metaphor of a wind turbine generator (WTG) as a visualisation of its structure for simple cross-comparison, where the use of a WTG metaphor enables greater clarity and understanding for the components of the model described in Table 21.[95] A WTG is also symbolic of sustainability in the modern world, given that the major challenge for many centres is to be sustainable beyond establishment funding or when the operating environment poses challenges. The WTG visualisation of the model uses visual communications to represent the complex mechanisms involved in the business model.

The power of visual thinking is reinforced by studies that have shown that the human brain is able to rapidly process and make sense of images even when they are out of sequence or mixed up, in as little as 13 milliseconds (Massachusetts Institute of Technology, 2014). The use of visual thinking is proven to be effective and "simply means using our innate visual abilities to help us see problems more clearly and to see connections that would have been invisible if we'd just talked about them" (Norton, 2010, p. 33). Furthermore, "images can show sequences, connections, patterns, and processes more quickly than bulleted text, and they are more memorable" (Cormier, 2009, p. 361). Osterwalder and Pigneur (2009) also use visual metaphors and images, in the form of a bento box, to communicate their business model canvas concept (section 2.17).

The validation process for the model through interviews (Appendix B) also indicates that the use of the WTG visual metaphor is effective for simplifying and communicating the complex nuances in the business model.

In a practical sense, a WTG has the simple purpose of generating renewable electricity from wind. It has a number of parts (refer to Figure 40), but in a nutshell, the blades spin around in response to the wind, controlled by the blade pitch control ⑫, which adjusts the pitch (i.e. the direction) of each blade. The blades connect to a central rotor hub ⑬. A WTG typically has three blades ⑪, which are considered more efficient and less costly to operate than a two-bladed WTG (the Guardian, 2011). The rotor hub is connected to the nacelle ⑥, which houses and protects the gears ⑩, the brake ⑨ and the generator ⑦ from nature's elements i.e. the weather. On top of the nacelle is an anemometer ⑧ to monitor wind speed. This whole upper portion of the WTG is connected to a yaw control ⑤ which enables a level of directional control, i.e. tilt and rotation. This is then lifted by a tower ③, which also houses an access ladder ④ and a door ⑭ to allow personnel inside to work on the WTG. The wiring from the generator links through to the grid ②. The tower is held up with a footing ①, which provides a stable foundation.

[95] Information on the use of metaphors - https://owl.english.purdue.edu/owl/resource/687/05/

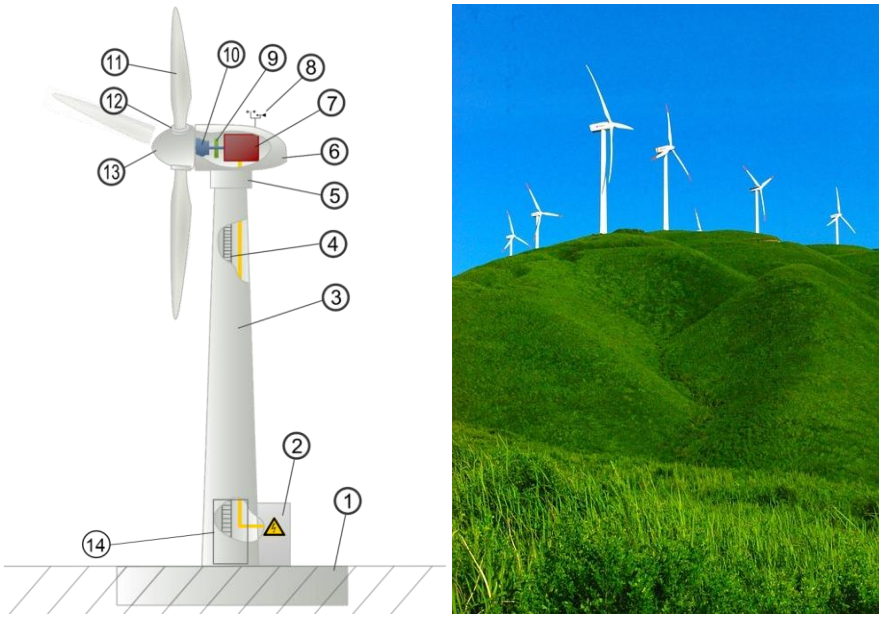


Figure 40 The components of a WTG (image on the left, adapted from: (Guion, 2014)): 1 – foundation, 2 – connection to the electric grid, 3 – tower, 4 – access ladder, 5 – wind orientation (yaw) control, 6 – nacelle, 7 – generator, 8 – anemometer, 9 – electric or mechanical brake, 10 – gearbox, 11 – rotor blade, 12 – blade pitch control, 13 – rotor hub, 14 – access door (Guion, 2014, p. caption 2). And wind turbines as a symbol of sustainability (image on the right, source: (Pixabay, 2013).

The WTG is typically installed on elevated land (Figure 40) to maximise wind capture and improve its potential for electricity output. Thus, a landscape with many WTGs linked together, i.e. a wind farm, on elevated terrain (hills) can optimally produce renewable electricity to benefit the economy and society. "Although many of the early wind turbines had two blades, only one or two megawatt-size turbines now exist in that style – everything else has three" (Milborrow, 2011, p. para 1). Hence, the three-bladed WTG is optimal compared to a two-bladed WTG.

5.3 THE FOUR DIMENSIONS OF THE WTG MODEL FOR CENTRES

The proposed WTG model for an IA centre is multidimensional (Decancq & Ana Lugo, 2013) and has four dimensions (4Ds): (1) structure; (2) interaction; (3) finance; and (4) activity. The two dimensions of *structure* and *interaction* in the WTG model are closely related. One dimension is the organisational structure and the other dimension of interaction is how the parts of the structure interact as a *system*, which is predominantly human-to-human interactions that are internal and external to an IA centre. Together, the structural and the interactional dimensions represent the overall organisational structure (McShane & Travaglione, 2003).

The *activity* dimension defines a centre's portfolio of activities, i.e. research, education and industry interaction (REI). The *finance* dimension represents a centre's revenue composition with respect to costs. This is depicted by the 4Ds in the diagram shown in Figure 41, where X represents any attribute of an IA centre and can be viewed as a function of the 4Ds: structure, interaction, activity and finance. In other words, there are independencies between the attributes of an IA centre (X) and the 4Ds, i.e. $X = f(structure, interaction, finance, activity)$, where X is a function (*f*) of the 4Ds.

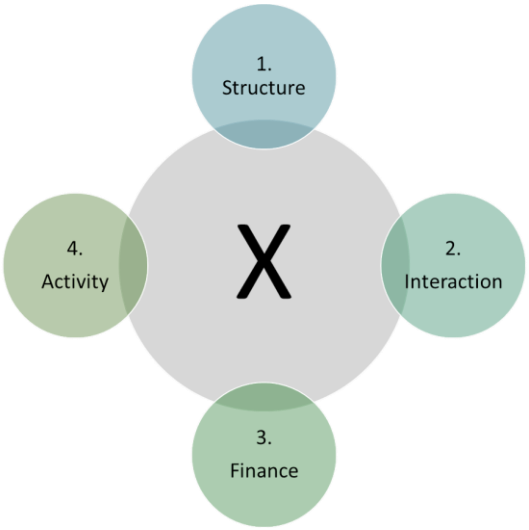


Figure 41 The 4Ds of the WTG model: structure, interaction, activity and finance; indicating that there are interdependencies for any given attribute of an AI centre, represented by the X with the overlapping circles of the 4Ds.

Any attribute (X) pertaining to a centre has representation in each of these 4Ds. For example, an IA R&D project (an example of an X attribute in Figure 41) for a centre could have a **structural** implication based on geographic proximity to resources in order to perform R&D tasks. From an **interactional** perspective, this means project management interactions and approvals from clients and centre management; while from an **activity** perspective, it is an R&D project with a specified project plan and contractual arrangements. Finally, from a **financial** perspective, the revenue generated from the R&D project must be offset against the cost of doing the project, taking into consideration operating costs such as staff salaries and university overheads.

The 4Ds recognise the multidimensional complexity of the nature of IA centres in reality (Chapter 4). This includes everything from leadership, reporting lines and value proposition through to portfolio activity and team dynamics. The next section shows how these 4Ds map to the WTG metaphor with the integration of the research findings (Chapter 4).

5.3.1 STRUCTURAL DIMENSION OF THE MODEL

The structural dimension (Figure 41) of the WTG model reflects how the WTG is fitted together and can be related to the organisational structure (McShane & Travaglione, 2003). There are many possible configurations with various pros and cons, but there is only one recommended model – an ideal model for an IA centre within an ANZ university, as shown in Figure 43.

The mapping of each of the WTG model's structural components (Figure 40) to the specific research findings (Chapter 4) is detailed in Table 22.

Table 22 Research findings (Chapter 4) mapped to WTG model parts, with reference to the WTG model.

WTG model (Figure 42)	Key research findings (Chapter 4) for the ideal recommended IA S&T centre within an ANZ university
(1) Host university arrangements	**Footing:** the foundation provided by the host department, including support arrangements within an MoU.
(2) Reporting lines	**Connection to grid**: executive reporting line within the university (e.g. dean or PVC).
(3) Industry membership consortium	**Tower:** membership consortium (paid end-user value-chain industry members, and in-kind research collaborators and professional bodies). The membership funding is used to underwrite operations, including the funding of key centre staff, e.g. the centre manager or hybrid academics. The members are attracted to the value-adding provided from having REI

	activity with tiered membership levels; they have strong relationships with the executive level in companies and many are likely to be alumni; companies latch on for CSR and/or commercial R&D reasons.
(4) Access for participants	**Access ladder:** access for industry members, host university academics (research associates) and students.
(5) Leadership and management	**Yaw control** (wind orientation control): centre leadership team: intrapreneurial serial innovators, a team of 2–3 people from a mix of: director and manager, plus co-directors, deputy-directors where appropriate; at least one of them is fulltime 1.0 FTE, i.e. one fulltime director or manager is dedicated to the centre.
(6) IAB (oversight)	**Nacelle** (housing): IAB (end-user executives, sometimes alumni, pan-industry and quasi-governance with university executive presence); meets 3–4 times per year and endorses strategic plan and business plans (transparent including finances, except for commercial-in-confidence R).
(7) Budget	**Generator:** the centre's available budget, which includes revenue and expenditure, impacted by variable and fixed costs. WTG generator is housed in the nacelle.^ ^Note: The combination of scope, time, budget and resources for the centre is viewed as the modified project management iron triangle, with resources in the middle of the triangle.
(8) Chair of the IAB	**Anemometer** (measures wind speed): industry end-user IAB chair (lead by example, heart of a volunteer, executive level, and a representative from the end-user membership consortium).
(9) Time constraints	**Brake**: the time available to conduct REI activities; WTG brake is housed in the nacelle.^
(10) Scope of activities	**Gearbox:** the scope of activities for the centre (REI activity); WTG gearbox is housed in the nacelle.^
(11) REI portfolios	**Three WTG blades**: REI activity portfolios, each with programs/projects. REI is held in equilibrium, thus enabling value-adding for stakeholders from CSR through to R&D. ▪ R includes consulting, technology transfer, R&D (basic, use-inspired, applied), grants and contracts with hybrid academics who work to industry timescales (professionally project managed), publishing, research training ▪ E includes undergraduates, undergraduate/postgraduate projects, outreach, scholarships ▪ I includes professional development, training, (academic and industry) conferences/workshops, networking events, communications (social media and newsletters), secondments/exchanges, field trips, internships/jobs.
(12) Project management	**Blade pitch control**: professional project management of the portfolio and steering committees are paramount for projects and activities in REI.
(13) Resources	**Rotor hub**: resources: staff and infrastructure (including access to labs and a shopfront), hybrid academics, industry/practice professors (translators), project managers, outreach, technicians and administrators (varies by size of centre), academics, postdocs and students, and subcontractors (research collaborators/consultants).
(14) Access for non-members	**Access door**: welcomes non-members to engage with the centre (i.e. not exclusive to members); this helps with project and funding opportunities, and to attract new members to counter member attrition, as well as for SMEs.
(15) Government support	**Support scaffold** (new addition to WTG model): government core funding is typically 3–7 years in ANZ, which is therefore temporary.
(16) Host university operating environment	**Landscape terrain**: the operating environment of the host university.
(17) Academic capability	**Hill**: the academic underpinning capability, e.g. measured by ERA and PBRF metrics in Australia and NZ, respectively.
(18) Operating environment in ANZ	**Weather**: geo-political, socio-economic, techno-environmental conditions.
(19) Strategic and business planning	**Spin of the rotor hub**: strategic plan (3 years, endorsed by IAB and stakeholders) and business plan (every 12 months, endorsed by IAB and progressively elaborated to deliver on strategy); they spin in the same direction.
(20) Impact (outcomes) generated from centre REI outputs	**Electricity produced by the WTG** is equivalent to the impact generated for the knowledge economy through the REI activity of the centre.

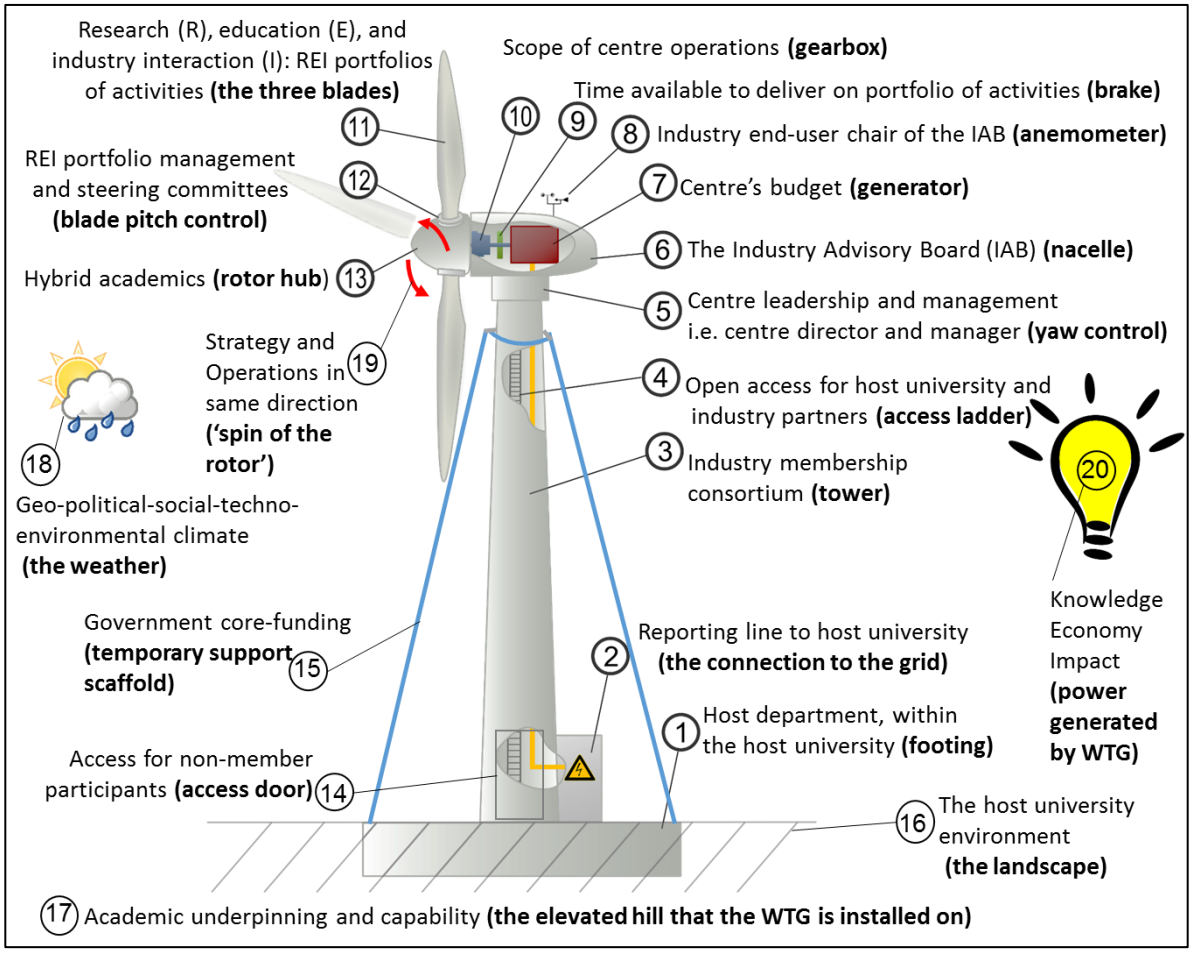


Figure 42 The WTG model for IA centres within universities (original unmodified image sources: (Guion, 2014; Pixabay, 2013)).

The variety of configurations have been identified by hypothetically determining the worst case representation for an IA centre WTG model (Table 23). This is the polar opposite (within the theoretical parameters of the research findings) of the recommended IA centre model, which has been defined by the research findings (Chapter 4). Articulating the two extremes as two points of reference on opposite ends of a spectrum, i.e. Table 22 versus Table 23, has enabled understanding of the implications of the differences between these configurations, leading to the variety of structural configurations that are possible for centres (Figure 43 and Figure 44).

Figure 43 shows all the possible configurations for a centre within a university and Figure 44 provides additional context to these various configurations. For instance, a multi-university partnered centre is equated to a mini-windfarm with a lead WTG. This can be extended to represent an institute within a single-host university by defining an institute as a collection of centres under a single umbrella. Hence, at the macro-level the institute could be represented by a single WTG and at the micro-level it could be viewed as equivalent to a multi-university partnered centre for its business model.

Table 23 The extreme opposite of the ideal centre model (Tabel 22) for an IA centre with reference to the WTG model in Figure 42.

WTG model (Figure 42)	The extreme opposite of the ideal centre model (Table 22) for an IA S&T centre within an ANZ university, as determined by the research findings (Chapter 4)
(1)	**No footing or foundation:** centre has a lease arrangement, no underwritten support from the host university to help with centre stability.
(2)	**No connection to grid:** no university reporting lines or not reporting to a university executive level.
(3)	**No Tower:** no industry membership consortium; may have a fee-for-service model with industry, but this requires significant business development resources and capability to ensure sufficient project income.
(4)	**No access ladder**: no affiliation to the centre by academic staff, i.e. no research associates from the host university nor industry members.
(5)	**No yaw control:** centre leadership: academic director (part-time 0.5 FTE) without a fulltime dedicated manager or director; if there is a manager, the manager is a postdoc without management experience; the culture is 'risk adverse and autocratic' rather than 'intrapreneurial leadership team'.
(6)	**No nacelle:** no industry advisory board or only a technical committee for the research program as a substitute for a strategic executive-level IAB; board members are not executive level from an industry end-user membership consortium of the centre and may be an internal group of academic staff.
(7)	**Generator:** the centre's available budget, which includes revenue and expenditure, impacted by variable and fixed costs. WTG generator is housed in the nacelle.^ ^Note: The combination of scope, time, budget and resources for the centre is viewed as the modified project management iron triangle, with resources in the middle of the triangle.
(8)	**No anemometer** (no way of measuring wind speed): no industry end-user IAB chair, hence missing opportunity to lead by example or have industry insight; may have an independent chair (not industry end-user or part of membership).
(9)	**Brake:** the time available to conduct REI activities; WTG brake is housed in the nacelle.^
(10)	**Gearbox:** the scope of activities for the centre (REI activity); WTG gearbox is housed in the nacelle.^
(11)	**1 or 2 blades (R or RE/RI):** R-focused (basic or use-inspired only), anti-consulting activity, postgraduate students are the only resource to perform projects; may conduct technical seminars, have research visitors, PhD projects and may participate in academic conferences, internships; 2 blades are less efficient than 3 blades. Hence, the WTG (centre) is less viable and produces less impact in the knowledge economy.
(12)	**No blade pitch control**: no professional project or portfolio management or steering; managed ad hoc by academic staff for centre projects (no consistency or project control measures with respect to deliverables).
(13)	**No rotor hub**: no dedicated resources, just postdocs and postgraduate students with academic participants (who have day jobs); no hybrid academics to perform projects for industry at industry pace across the R&D spectrum, including consulting, product development and testing.
(14)	**No access door:** an exclusive (closed community) member-only centre with no access for non-members or ad hoc SMEs that want to undertake short-term projects (consulting/applied research).
(15)	**No support scaffold:** no government core funding, but may receive government research grants.
(16)	**Landscape terrain:** the operating environment of the host university.
(17)	**Foundation:** weak academic underpinning capability, but may draw on other universities for support, i.e. to co-host the centre across several universities.
(18)	**Weather:** geo-political, socio-economic, techno-environmental conditions.
(19)	**No strategic plan and/or business plan** for executing the strategy: perhaps using a funding proposal as a substitute, if funded by government or internally funded by the host university.
(20)	**Electricity generated:** KE outcomes via activities; if centre is only R-focused, then it does not fully impact on the KE (not aligned with the entrepreneurial university mantra, with missions of social and economic development in addition to research and education).

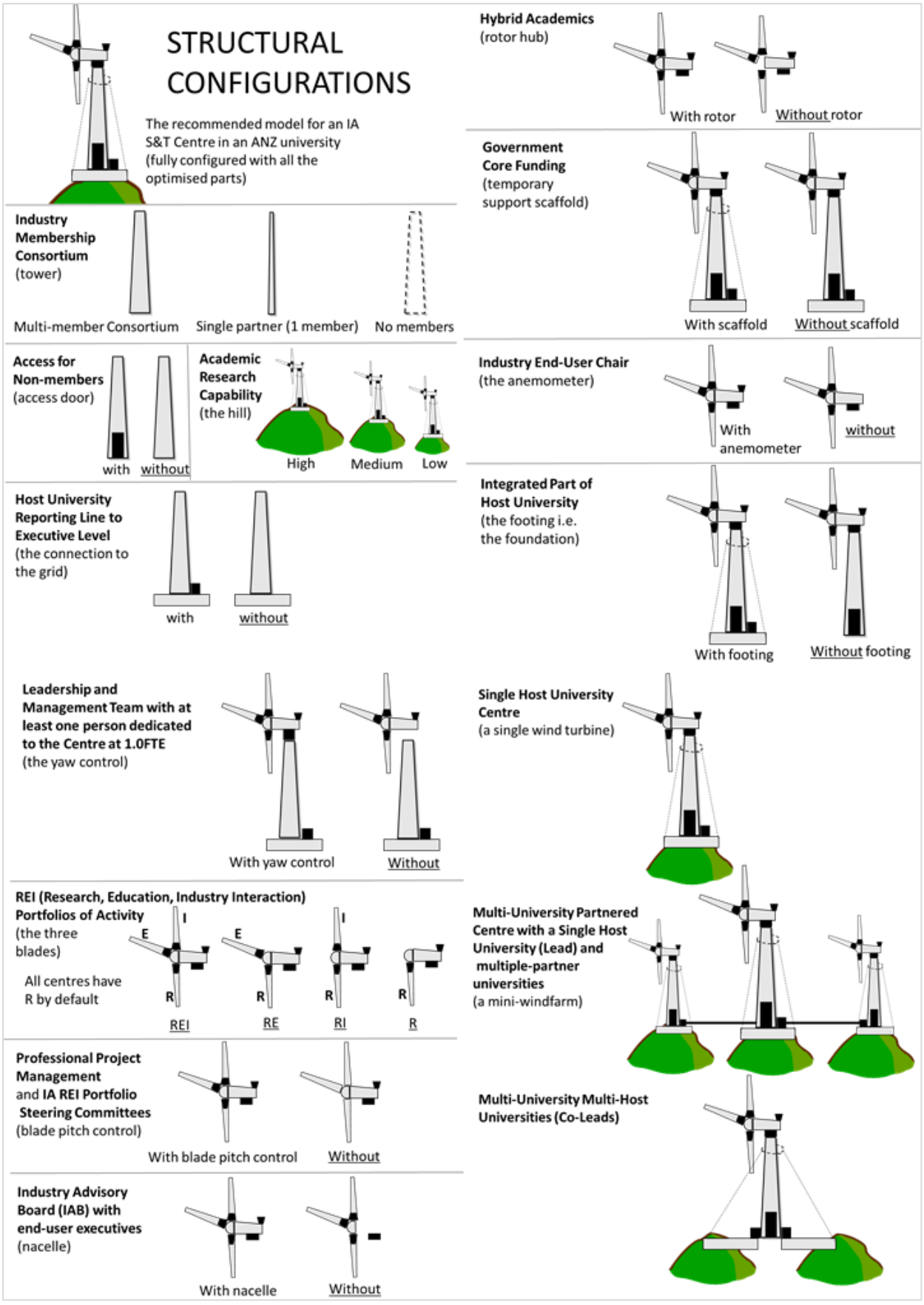


Figure 43 The structural dimension of the WTG model with possible configurations, and the recommended model (top left).

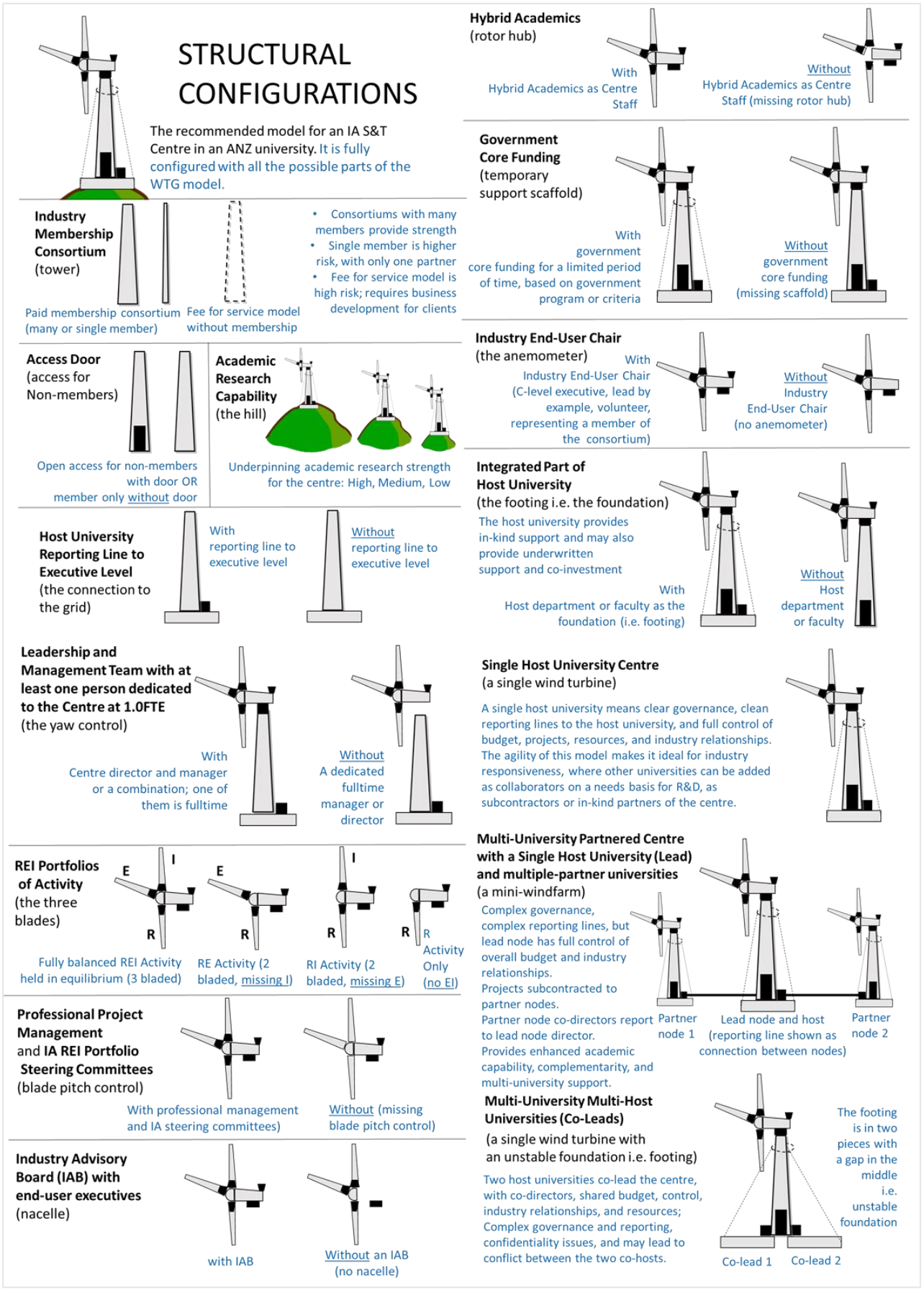


Figure 44 Structural dimension of the WTG model with descriptions of possible configurations; the recommended model (top left).

5.3.2 INTERACTIONAL DIMENSION OF THE MODEL

The interactional dimension of the WTG (Figure 41) refers to the organisational structure, in a way integrated with the structural dimension presented previously (subsection 5.3.1). This includes aspects such as the division of labour, as well as the coordination, communications, workflow and formal control of power for activities of the centre (McShane & Travaglione, 2003).

Based on the results and discussion (Chapter 4), an IA centre can be defined as having the following organisational characteristics (McShane & Travaglione, 2003): formal and informal communications; formal hierarchy; flat structure with a wide span of control; centralised decision-making power; a team-based structure when centre staff are working within the host university; and adoption of a virtual corporation approach for large collaborative R&D projects with partners, i.e. on demand.

These organisational characteristics are described in Table 24 and impact on the functional (interactional) dimension of the WTG model. This is shown in the diagram in Figure 45, with the red arrows indicating the interactions and their directions.

Table 24 Organisational characteristics mapped to IA centres (McShane & Travaglione, 2003).

Organisational characteristic	**Meaning with respect to IA centres, as per results and discussion in Chapter 4**
Formal and informal communications	The interconnected relationship within the centre's staff, the IAB, the host university staff and key industry partner contacts.
Formal hierarchy	This applies to the organised way in which the centre operates with a chain of command starting with the centre director or co-directors to the manager, in regard to the way the staff of a centre or project participants report up, e.g. R&D portfolio management decision-making.
Flat structure with a wide span of control	A centre operates on a flat structure which has a leadership team of two or three individuals, with the centre staff reporting to them.
Centralised decision-making power	In regards to the way the centre staff or project participants report up for decision-making to the leadership team with the centre director and manager, e.g. R&D portfolio management decision-making.
Team-based structure	When the centre staff are working within the host university, this allows for the staff to be working across a number of projects and activities, depending on their skills and capabilities, to complement each other through a team-based, cohesive approach.
Virtual corporation	This applies when the centre is working on a number of collaborative R&D projects involving multiple industry partners and other research organisations and universities. The virtual teams unite for the purpose of R&D projects and disband after the mission is accomplished, within a set budget, scope and time.

The recommended model for an IA centre in an ANZ university has the relevant organisational characteristics for its internal and external interactions and engagements, as indicated in Table 24 and shown in Figure 45. This is within the functional dimension of the 4D WTG model.

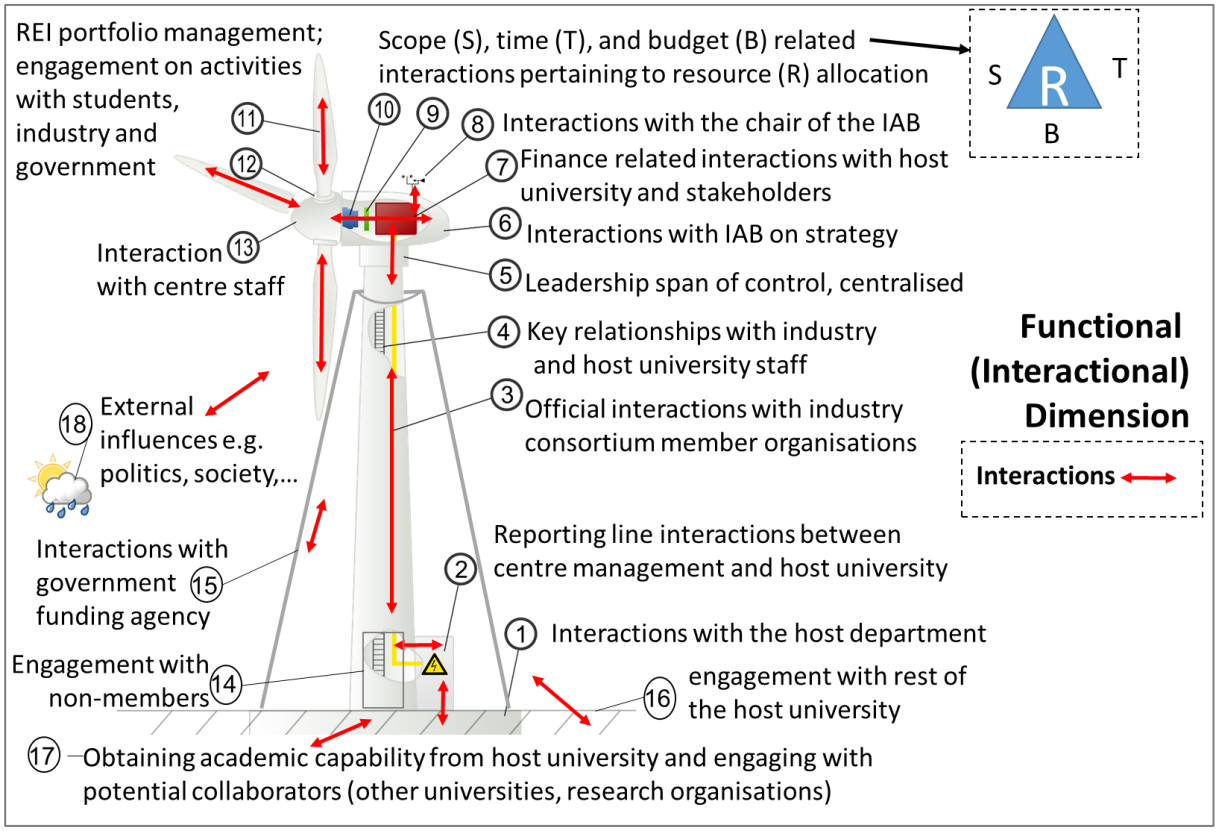


Figure 45 The interactional dimension of the WTG model showing interactions (internal and external), underpinned by the research findings (Chapter 4); original image sources (Guion, 2014; Pixabay, 2013).

The interaction dimension of the 4D WTG model (Figure 41) addresses the internal and external interactions required for an IA centre, as determined by the research findings (Chapter 4) and highlighted by Table 24. The interactions span informal and formal approaches, which are relationship based from a human-to-human perspective and formal from an organisation-to-organisation perspective.

Some of the interactions are representative of influences on the centre from the external and internal operating environments, such as government funding agencies or indirect external forces driving host university changes or strategy. These interactions potentially pose challenges for a centre and the best that a centre can do in response is to mitigate these challenges through countermeasures within the interaction dimension, with the list of extracted research findings pertaining to interactions as identified in Table 25.

Table 25 Key approaches extracted through the research results for mitigating challenges in the interaction dimension as a recommendation for the ideal ANZ business model.

Key approaches for Interaction	Description
a) MoU with Host	Memorandum of Understanding (MoU) with host department or faculty
b) IAB Terms of Reference	Terms of Reference for Industry Advisory Board (IAB)
c) Performance incentives	Performance Incentive for centre director (at least 0.5 FTE)
d) Centre manager	Qualified and/or experienced centre manager (1FTE)

e)	Academic steering	Academic steering committee(s) to provide feedback on REI activity
f)	Research associates	Officially involves academics as research associates of the centre i.e. viewed as extended centre staff members
g)	Hybrid academics	Hybrid academics on parallel academic salary scale, as centre staff
h)	Industry professors	Industry professors to spearhead R&D themes at market-rate salaries
i)	IP position	Default intellectual property rights (IPR) position on R&D projects
j)	IAB oversight	IAB for high level strategic view of all REI Activity, not R&D projects
k)	Strategic plan	Three year strategic plan with REI pillars (Objectives, Goals, KPIs), endorsed by the IAB and host university
l)	Business plan	Annual business plan to deliver on strategic plan under REI pillars (endorsed by IAB and progressively elaborated at each IAB meeting)
m)	Project management	Professional project management (PM) on all R&D projects for industry: scope, time, budget, resources allocation ('PM Iron Triangle')
n)	Reporting lines	Reporting line of centre director to executive level at host university
o)	IAB representation	Host university executive level representation on the IAB
p)	Administrative support	Administrative support from host department or dedicated centre staff
q)	Operating space	Dedicated operating space and/or shop-front for the centre, with professional website and social media
r)	Customer relationship management	Simple customer relationship management (CRM) for industry and research contacts
s)	Membership consortium	Membership consortium with a value-chain pan-industry approach, with SMEs, large national companies, multinationals, and peak bodies (industry associations)

5.3.3 THE FINANCIAL DIMENSION OF THE WTG MODEL

Based on the research results (sections 4.2, 4.4, 4.8 and 4.9), Figure 46 presents a summary of all theoretical revenue streams for an IA centre within an ANZ university, with revenue sources that carry greater importance highlighted, while other sources are left unhighlighted.

Translating these results, Figure 47 provides a synopsis of the net financial position of an IA centre with respect to the financial dimension of the 4D WTG model, where a net financial position equal to or greater than zero means that a centre is financially viable. Figure 47 shows the flow of revenue ('green arrows') into the IA centre (WTG) and the outflow of expenditure, i.e. costs ('red arrows') away from the WTG.

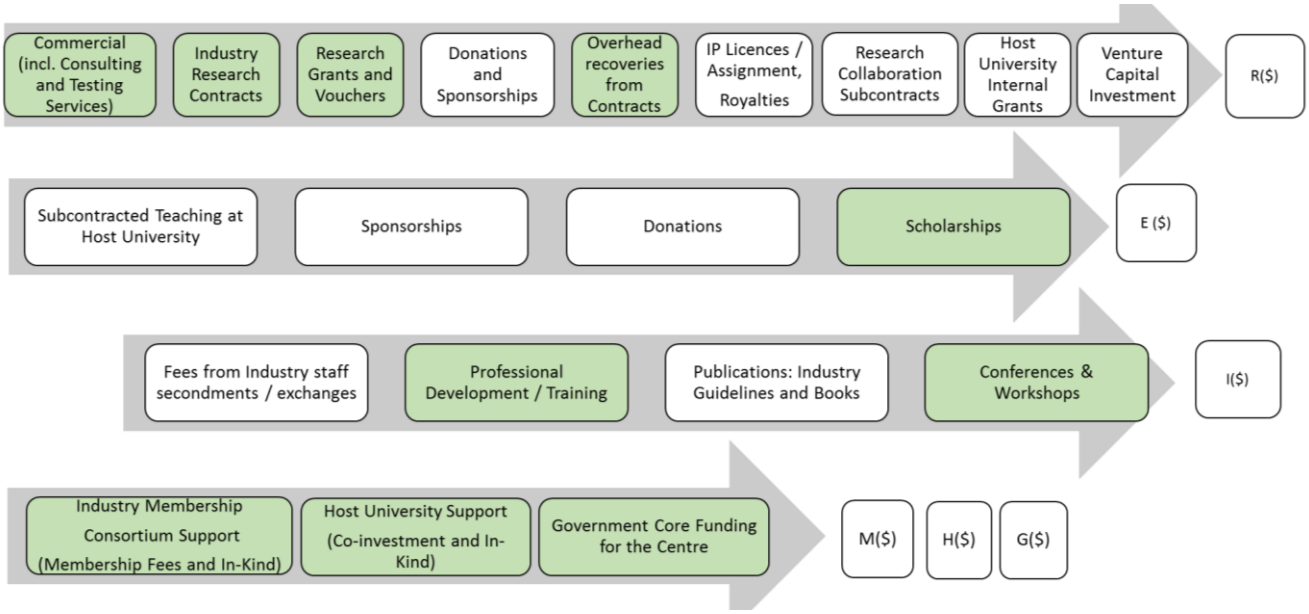
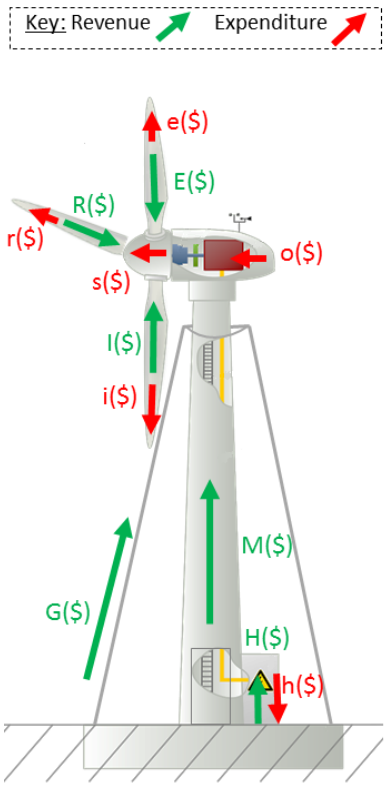


Figure 46 Recommended revenue streams for a centre, based on the findings (Chapter 4), with key revenue sources highlighted.



Revenue Streams:

Income ($) = R ($) + E ($) + I ($) + M($) + H($) + G($)

Where:

R($), E($), I($) = income via research, education, and industry interaction portfolios

M($) = industry consortium membership fees (variable) + in-kind support

H($) = host university co-investment support (variable) + in-kind support (underwritten)

G($) = government core funding support (fixed for a period of time)

Expenditure Streams:

Cost ($) = r($) + e($) + i($) + h($) + o($) + s($)

Where:

r($), e($), and i($) = R, E, I portfolio costs when delivering activities (variable)

h($) = space charges (fixed) + overheads charges (variable)

o($) = general operating expenditure (variable) + capital expenditure (variable)

s($) = staff cost; mix of fulltime or part-time (fixed cost) + casual staff (variable cost)

The Financial Position:

Income ($) – Cost ($) = End of Year Net Position ($)

Where, **End of Year Net Position ($) ≥ 0 is a requirement for viability**

Figure 47 Overall financial dimension of the WTG model, based on the research findings (Chapter 4); WTG image: (Guion, 2014).

The sources of revenue shown in Figure 46 in the financial dimension of the WTG model can be grouped into two categories: (1) key sources of income; and (2) optional sources of income. This

guides an IA centre in deciding which sources of revenue are crucial (highlighted boxes in Figure 46) and what other revenue sources could be considered (unhighlighted boxes) either at the establishment phase or downstream. This can then feed into an IA centre's strategic plan, endorsed by the IAB and, ultimately, its business plan, also endorsed by the IAB, to guide strategic operations towards valuable outcomes for stakeholders, and impact for society and the economy at large, while generating revenue so as to be financially viable.

This also highlights the importance of maintaining a net positive revenue position relative to the costs for an IA centre, in order to be financially viable (Figure 47), i.e. to achieve a net financial position annually of zero or higher. Hence, an IA centre is essentially a not-for-loss enterprise, akin to a social enterprise (Bugg-Levine, et al., 2012), which aims to be cash-flow positive year-on-year with the provision to carry forward any profit, rather than making a profit per se. Its aim is to cover its own operating costs. This helps centre management determine which activities are a revenue advantage or a disadvantage for an IA centre, depending on their adopted version of the WTG model; many configurations are possible with pros and cons for each, e.g. a two-bladed WTG model versus a three-bladed WTG model, as presented in the previous section on structural configuration (subsection 5.3.1).

The recommended model for an IA centre within an ANZ university utilises all the revenue streams indicated in Figure 47 in the financial dimension of the 4D WTG model.

5.3.4 THE ACTIVITY DIMENSION

The activity dimension (Figure 41) defines the array of recommended activities that can be undertaken by an IA centre through its portfolios of research (R), education (E) and industry interaction (I). These are represented as the three blades of a WTG (Figure 42), as shown in Figure 48, Figure 49 and Figure 50 for R, E and I, respectively, referred to as REI activity in the WTG model.

Output from REI activity equates to KE impact (subsection 4.9.2). Therefore, an IA centre must endeavour to keep REI in equilibrium (section 4.9) in order to satisfy stakeholder expectations, i.e. industry, the host university and government, and also generate sufficient revenue to offset expenditure (Figure 47).

The recommended model for an IA centre within an ANZ university has all the REI activity indicated in Figure 47, in the activity dimension of the 4D WTG model, which is represented by a three-bladed WTG. The highlighted activities are considered essential, while the unhighlighted activities are considered less crucial, based on research findings (Chapter 4).

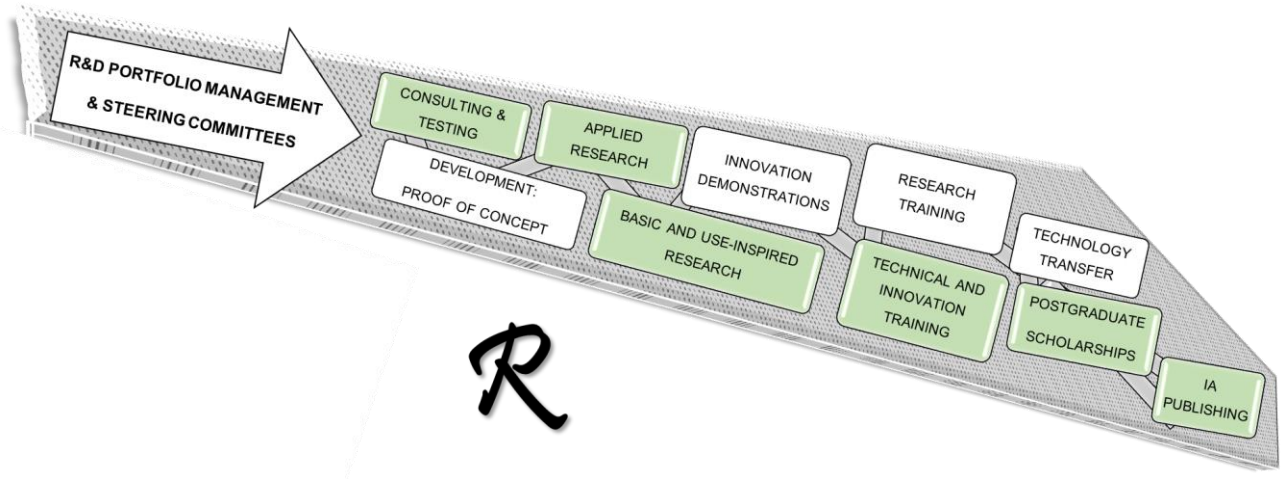


Figure 48 The research (R) portfolio of recommended activities for an IA centre, based on the findings (Chapter 4), including portfolio management and steering committee presence; represented by the R blade of the WTG model; with essentials highlighted.

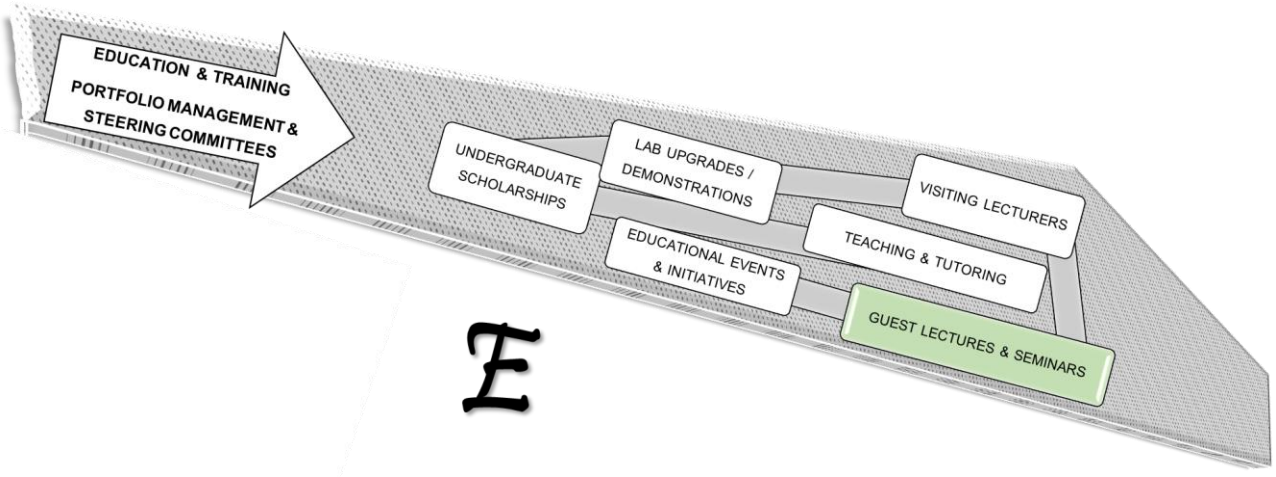


Figure 49 The education (E) portfolio of recommended activities for an IA centre, based on the findings (Chapter 4), including portfolio management and steering committee presence; represented by the E blade of the WTG model; with essentials highlighted.

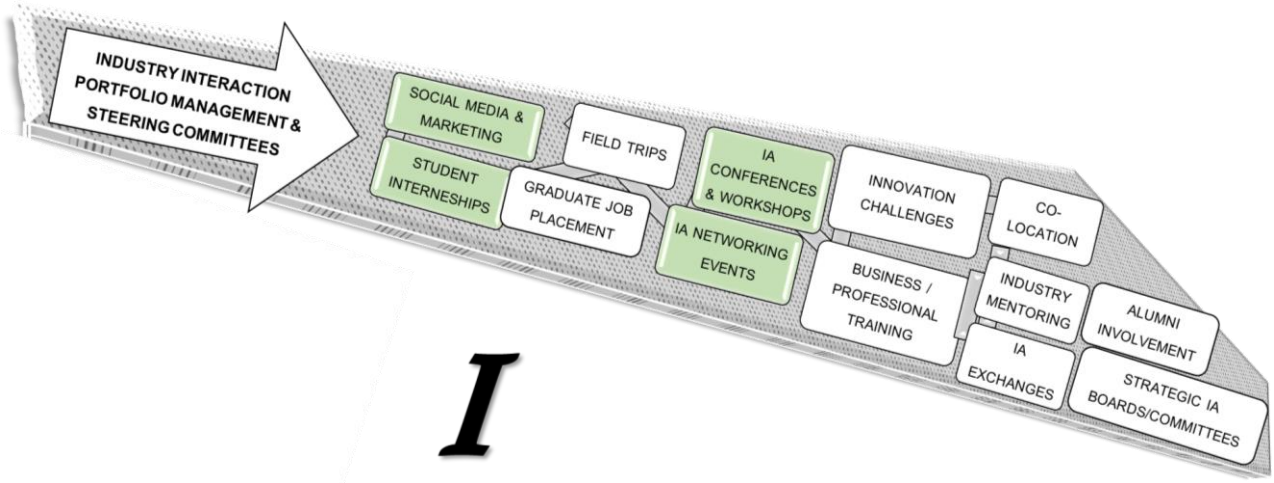


Figure 50 The industry interaction (I) portfolio of recommended activities for an IA centre, based on the findings (Chapter 4), including portfolio management and steering committee presence; represented by the I blade of the WTG model; with essentials highlighted.

5.4 SUMMARY OF THE RECOMMENDED BUSINESS MODEL FOR S&T CENTRES

A summary of the recommended business model and how it links to the key research findings is shown in Figure 51. The key research findings, represented by the outer circles, overlays onto the four dimensions (4D) of the recommended model, depicted by the inner circles, which underpin the recommended business model for IA S&T centres within ANZ universities, visualised by the WTG image in the middle. Note that the recommended model has the optimised or complete characteristics described for structure (Figure 43), interaction (Table 25), finance (Figure 46 and Figure 47) and activity (Figure 48, Figure 49 and Figure 50). The Centre Viability Index (CVI) has been omitted from the summary, since it is yet to be fully developed with the level of academic rigour required. However, preliminary testing indicates that it is plausible, once the weightings are refined for the indices (Appendix D).

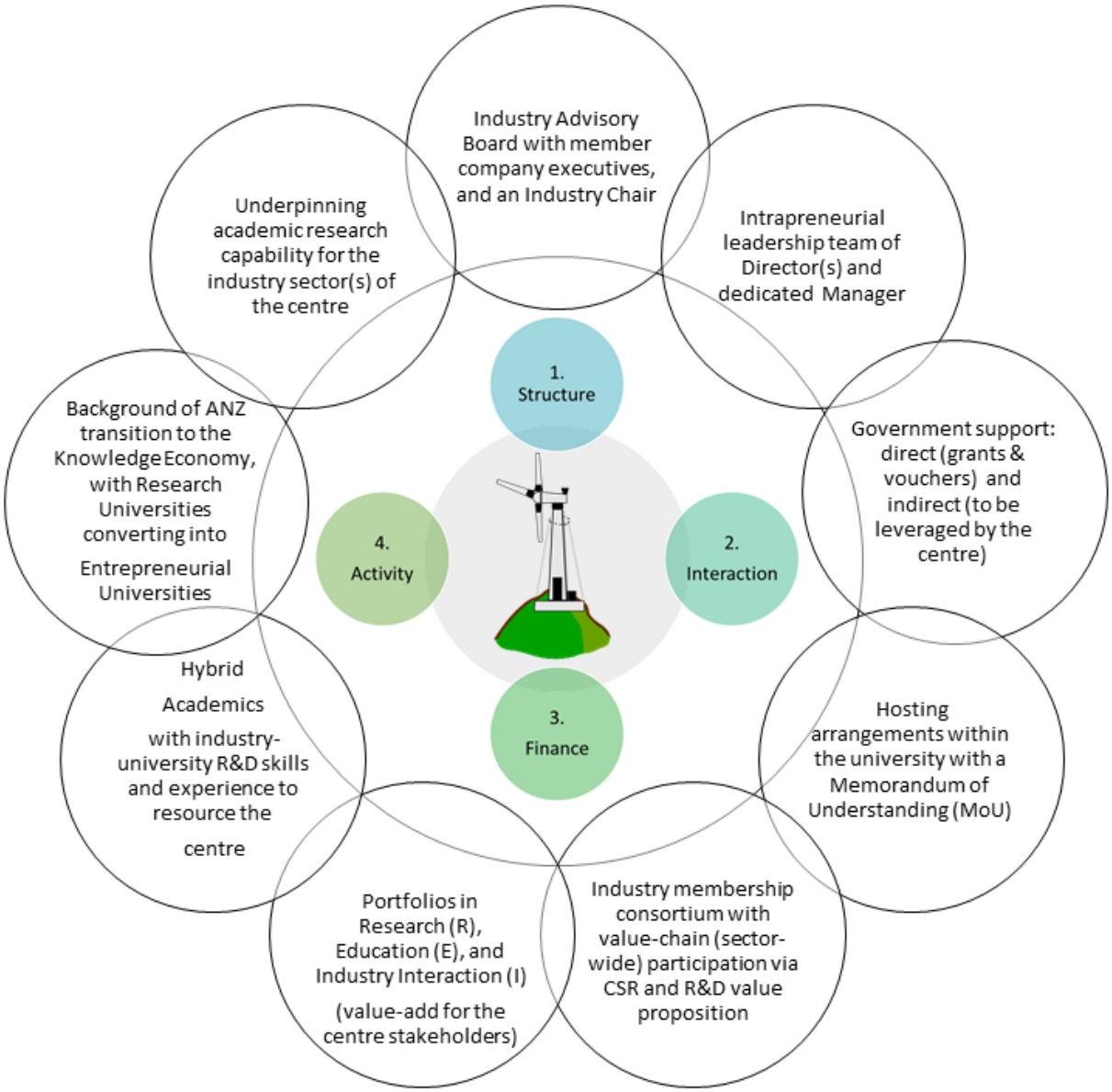


Figure 51 The key research findings (outer circles), mapped to the 4Ds (inner circles), which underpin the recommended business model for IA S&T centres within ANZ universities, visualised by the WTG image in the middle that is configured to be fully optimised.

5.5 APPLICATION OF THE MODEL

The process of participant-observer insider-led research has enabled the recommended business model to be improved and, conversely, the findings from the research have already been directly applied and implemented in a dozen research centres in ANZ (Figure 52), thus demonstrating early-stage research impact from this project. This has not only improved the robustness of the model, but also demonstrates that it is valid and is feasible in practice. For example, the EPECentre has been self-sustaining without core government funding since 2002 and hence presented an ideal reference business model that had never had to contend with not having core government support, which is one of the major issues for centres in ANZ and globally (i.e. surviving past the end of the government core funding period)(subsection 2.10.1). The EPECentre has gone on to drive impact through its REI activity, resulting in a four-fold increase in graduate numbers for the power industry in New Zealand, R&D output with large-scale national programs, and technology development and knowledge

dissemination, with over 35 sector-wide value-chain industry members and a supportive industry advisory board and host university (section 4.9.2).

The application of the research findings to the EPECentre commenced in parallel with the research study in 2005. Therefore, the EPECentre model has been enhanced over the period 2005–2011, during the participant-observer period with the EPECentre, while the EPECentre became a vehicle for testing and validating the research components of the business model.

The research findings have also been applied to the establishment of the Ancient Mediterranean Program at Macquarie University (Figure 52) in 2011, which is a non-S&T centre focused on archaeology. However, this demonstrates the possibility of configuring the model to non-S&T domains. This indicates potential generalisability for the model for non-S&T centres in ANZ universities, although it has not been tested beyond this single case. There is scope for future research to consider the specific applicability of the recommended business model to non-S&T centres within ANZ universities, covering academic areas such as arts, commerce and sociology.

Lastly, the findings for the model has been tested on ten centres at Monash University (2012–2016). The following are the general divergences, overarching above all the 4Ds (Figure 41), observed for the centres explored during the application of the research at the field-site universities:

- There was no significant difference between Australia and NZ as far as centre development was concerned, from the perspective of a university, when developing centres. However, NZ centre development activity was typically viewed as a national endeavour with nationwide participation, while centre development in Australia tended to concentrate efforts within state boundaries, i.e. more state-wide participation focus, rather than national.
- Universities placed a higher status on centres designated as institutes. However, externally from the view of government and industry, there was no perceived difference between other centres and those centres designated as institutes.
- Centres that addressed global challenges in order to create socio-economic impact were perceived to be more worthy of support from the university, especially when it was aligned with government funding signals for research, i.e. this influenced the levels of financial support provided.
- The mindset of participants depended on the IAG Code (Figure 2).
- Host university buy-in and alignment with the mission and theme of the centre influenced the establishment phase in shaping the business model, e.g. the level of host support provided, including seed investment.
- Government priorities influenced the level of support possible from the host university and the industry, reflected by reports, media statements and the funding bodies, e.g. the ARC in Australia and the MBIE in NZ.
- Visionary leadership was crucial in progressing a centre to establishment, and required intrepreneurial champions (e.g. centre directors and senior university managers) within the university environment. The presence of such champions resonated with centres having business models more similar to the recommended business model (Chapter 5).
- Industry champions for a centre usually became exemplars for other industry participants, to promote partnership with the centre. These visionary industry champions usually ended up on the Industry Advisory Board (IAB) of the centres.
- There was a tendency for smaller SMEs to prefer non-membership of centres when compared to large SMEs and large firms, who were open to membership of centres. Conversely, there was a tendency for SMEs to expect some level of government subsidy to support their involvement in a centre, e.g. matched funding grants or R&D vouchers. Therefore, the model allows for small SMEs

to access the capabilities of a centre as non-members, while allowing larger SMEs and large firms to be more heavily involved as members (Figure 45).

- The mindset of having a local outlook versus a global outlook for centre participants impacted on the boldness and scale of the scope of a centre, and affected the activity dimension (subsection 5.3.4).
- Industry partners from the utilities and services sectors tended to have a medium to long-term view of centre participation, where they valued knowledge-sharing across the sector and jointly influencing government on issues that impact the sector as a whole.
- Industry partners who were producers or manufacturers were more inclined to prefer short-to-medium term engagement with a centre and IP considerations were more important, as well as government leveraging on any funds invested in working with the centre.
- Partnering with industry associations enabled significant credibility, connectivity and industry insight for a centre. Industry associations also produce road maps for a sector, where a centre could position itself as a vehicle to deliver on the objectives of the road map with respect to collaborative innovation, training and knowledge transfer.

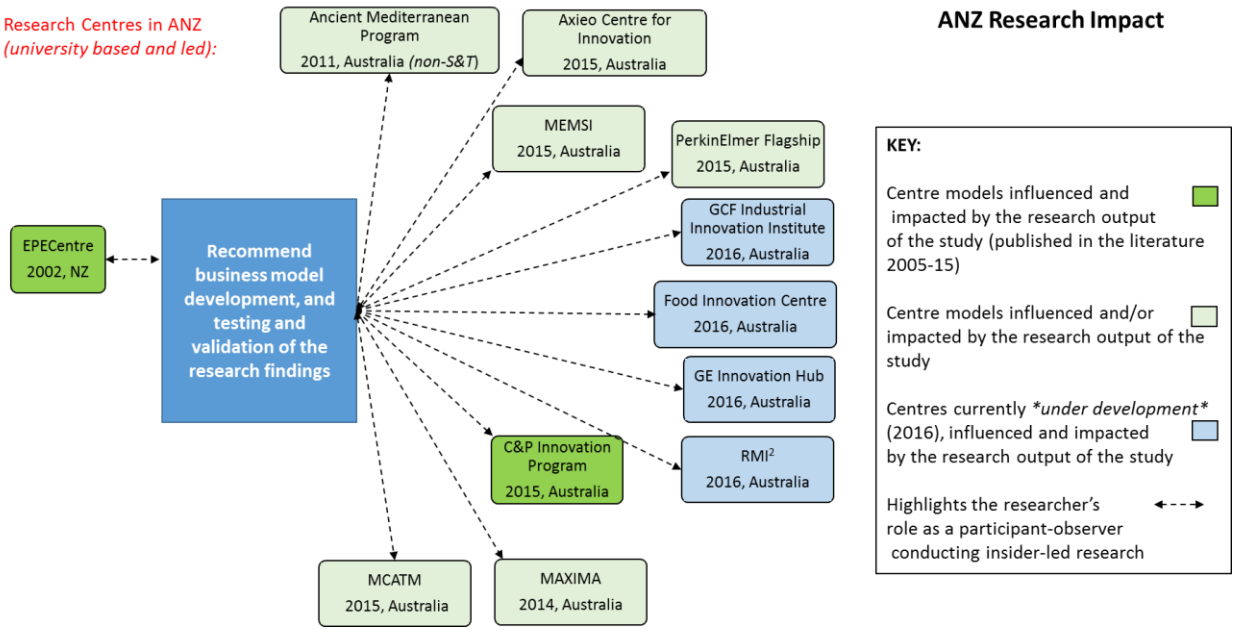


Figure 52 The current research impact achieved from the research output of this project.

CHAPTER 6. CONCLUSION

In the transition to the knowledge economy being driven by science and innovation, universities in ANZ have a key role to play as knowledge generators and educators. Research universities of the 20th century are transforming into entrepreneurial universities of the 21st century in order to deliver on missions around research, education and socio-economic impact. IA collaborative S&T centres are increasingly becoming the vehicle of choice for universities to deliver KE impact in pursuit of this transition. However, without guidance through a business model framework for centres specifically designed for universities, centres will continue to suffer from the lack of a robust foundation, which may render them non-viable beyond their initial seed funding. The objective of this research has been to develop a business model recommended for IA S&T research centres within ANZ universities.

This study has been performed with the researcher as a participant-observer conducting insider-led research across three ANZ field-site universities from 2005 to 2016. The field-site universities were: (1) University of Canterbury in New Zealand; (2) Macquarie University in Australia; and (3) Monash University in Australia. This is in addition to a major longitudinal case study of an IA collaborative research centre, the Electric Power Engineering Centre (EPECentre), at the University of Canterbury over 2005 to 2011, which has resulted in a number of publications.

The research has used a mixed-method research methodology, which was qualitatively led using modified Grounded Theory (GT). However, unlike traditional GT (using interviews), this research has been driven by the major case study of the EPECentre and enhanced through field-site observations across the three ANZ universities. This process has drawn out the key research findings and themes, which have been enriched by additional qualitative data sourced from the literature and quantitative data from sources such as the OECD and the Australian Institute of Management (AIM). In addition, validation interviews have been conducted with senior representatives from industry, university and government, in order to test the final research findings and to determine the feasibility of the recommended business model. This has also served to minimise researcher bias.

The main research objective has been to formulate a business model recommended for IA S&T collaborative research centres for ANZ universities. The research project has focused on research centres that are university led and based. This has been differentiated from centres co-located in a university setting that are not part of the university, such as Australian Cooperative Research Centres (CRCs), which are independent, industry led research organisations that may choose to be co-located in a university.

The following sections summarise the key research findings and conclusions from the research, and outline the importance of the research, the scope for future research and the research recommendations for policymakers and practitioners in ANZ universities, industry and government.

6.1 SUMMARY OF KEY RESEARCH FINDINGS

A recommended business model for IA S&T collaborative centres within ANZ universities had not been previously considered in the literature. Indeed, business model theory had not been applied to industry–university research centres previously.

A number of key contributions to this field of research have been ascertained during this study that have fed into the recommended business model. These are:

1) ANZ is in transition to becoming a knowledge economy and consequently ANZ research universities are correspondingly transitioning into entrepreneurial universities.

2) The ability of the host university to support a centre through its academic research capability in multidisciplinary areas aligns with the industry sector of the centre (i.e. the underpinning academic research capability of the host university).
3) The specific hosting arrangements between a centre and its host department or faculty within the host university should be underpinned by a memorandum of understanding (MoU) which serves as an instrument for setting mutual expectations and boundaries on matters such as: academic participation in the centre; infrastructure access for the centre; approval processes for the centre within the university; and financial protocols (e.g. allocation of university overhead recoveries).
4) An intrapreneurial team leadership and management approach to S&T centres are recommended, with the team comprising a centre director and/or co-directors, deputy directors or a combination thereof, and a dedicated centre manager with professional management capability.
5) Centres should recognise that government support in ANZ for an S&T centre may be direct and/or indirect (i.e. can be leveraged to fund centre activities and for customising the value proposition to industry participants), including: core government program funding for centres; research grants and innovation vouchers; R&D tax credits for industry; charitable tax exemptions for industry; and block grant funding incentives for universities.
6) An industry membership consortium is considered best practice for a centre, with SMEs, large companies, multinationals and industry associations, i.e. sector-wide value-chain participation, with an open-access policy to allow a centre to openly engage with non-members. This ensures alignment with the value-chain necessities in the transition to the KE, i.e. business-to-business (B2B) collaboration in ANZ for innovation, mitigating member attrition by enabling potential new members to engage with the centre and being flexible to allow ANZ SMEs (99% of all industry in ANZ) to engage with the centre without requiring membership (e.g. ad hoc small R&D projects).
7) An end-user industry advisory board (IAB), with executive-level participation from industry centre members and the host university, to provide strategic advice to the centre's leadership and management team is seen as critical. In addition, the IAB should be chaired by a senior industry executive drawn from the industry membership consortium of the centre, i.e. a willing participant (volunteer) with a vested interest in the success of the centre and the ability to lead by example. A university executive presence (i.e. key reporting for the centre) on the IAB improves decision-making times within the host university operating environment. This allows the centre to be responsive and agile to opportunities, without diverting the leadership team to seek internal, separate approvals, which may lead to uncertainty and delays.
8) A portfolio of activities under the three pillars of research (R), education (E) and industry interaction (I) is defined as REI activity. REI enable a centre to deliver diverse stakeholder (industry, university and government) value-added benefits, while adapting to the ANZ operating environment, i.e. REI activity held in equilibrium, which in turn could lead to KE impact for ANZ, as stakeholders benefit from the REI activity such as the creation of new, highly skilled jobs for graduates, investment into the commercialisation of research and providing competitive edge for industry members through centre R&D outputs.
9) Hybrid academics (defined as researchers who have worked in both industry and academia) are essential resources for S&T centres within ANZ universities, and supplement traditional academic research fellows, postdoctoral researchers and postgraduate students. The hybrid academics are able to undertake IA collaborative R&D projects at the pace of industry and compensate for the lack of time available to academics to directly perform project tasks (i.e. academics have teaching, research supervision and university administration duties that take priority). This also enables academics to provide technical input and participate in a diverse array of centre R&D projects, including consulting projects, where ANZ academics have the provision to spend up to 20% of their time and receive consulting fees as an incentive. The hybrid academics can also be utilised to lead major research programs, teach university courses, facilitate industry–university

workshops, mentor and supervise postdoctoral fellows and students, and devote themselves to research commercialisation initiatives, as well as contributing to the publishing efforts of the host university.

The recommended business model for S&T centres has been determined to be four-dimensional (4D), with each of these dimensions co-existing in parallel, where:

- **The 4Ds** are defined as – **(1) structure** (organisational structure), **(2) interaction** (internal and external interactions of the centre, including human-to-human relationship interactions, but also organisation-to-organisation, i.e. informal and formal), **(3) finance** (the key sources of revenue for a centre and associated cost impediments to achieve an annual cost neutral position) and **(4) activity** (the portfolios for research, education and industry interaction for the centre, i.e. REI activity, which delivers value-adding to stakeholders, provided the centre keeps these activities in equilibrium with the needs of the stakeholders in industry and the university, and in some instances government).
- The 4D model has been described using a wind turbine generator (WTG) metaphor, firstly, as a tool for visualising and configuring the business model, which can be used to optimise new and existing centres, and to cross-compare centres within universities, and secondly, as the ultimate symbol of self-sustainability, which is a major challenge for IA research centres in ANZ and overseas. This arises when core government program funding ceases for a centre and/or a centre is unable to adapt to operating conditions and therefore fails to meet the ongoing expectations of its stakeholders in industry, university and government.
- Components of the recommended business model have been tested and applied to more than 20 IA collaborative initiatives over 2005–2016 in parallel with the research effort, including 12 research centres across the ANZ the field-site universities, i.e. University of Canterbury, Macquarie University and Monash University, enabled by the researcher being a participant-observer conducting insider-led research. This has had three benefits for the research project: (1) it has informed the development of the recommended model for ANZ; (2) it has tested the robustness of the model in practice; and (3) it has provided immediate research impact from the research, i.e. adoption of the research findings in practice.
- Finally, the main research findings and the recommended model have been validated through interviews in 2016 with senior representatives from university, industry and government. This has provided three additional benefits: (1) it has validated the key research findings and shown acceptance of the recommended model; (2) it has served as a countermeasure for reducing potential researcher bias; and (3) it has demonstrated the feasibility of the model with key practitioners deeply involved with facilitating or leading industry–university centres.

As an extension of the research output, it has been found that the 4D recommended model in combination with the WTG metaphor presents the opportunity to develop weighted indices across each of the 4Ds and an overall Centre Viability Index (CVI) could be derived (Appendix D). Preliminary analysis of 10 S&T centres indicates that this is highly feasible and hence there is scope to feed the research outputs into a prospective business model development toolkit for IA S&T centres in universities, perhaps in the form of a niche software application for practitioners and senior management in universities, and policymakers responsible for centre program funding in government.

During the course of the research synthesis, a simple new method for codifying various research centres has been devised to categorise centres, which in itself has become a useful research output. The method developed is called the IAG Code, where IAG is an acronym for industry, academia (university) and government. Use of the IAG Code enables the rapid identification of a centre type from the perspective of a university, with the following codes: IA, I*A, IAG, I, IG, I*G, G, AG and A.

6.2 RESEARCH VALUE FOR SCHOLARS AND PRACTITIONERS

For scholars: this research advances the field of literature on university-based and university-led IA S&T collaborative research centres, and S&T research centres in general within universities. This is because it is the first time that business model theory has been combined with the multidimensional aspects of university research centres, underpinned by empirical research which has been validated as well as field-tested in ANZ and demonstrated to work. Furthermore, having an underpinning recommended business model for IA S&T centres within ANZ universities means that scholars from different discipline areas of research can use this as a platform for further exploration of the topic in S&T centres in universities pertaining to each of the four dimensions (4Ds): organisational structure (management); interactions (psychology); finance (economics); and activity (innovation management).

For practitioners: the recommended business model presents a robust framework (based on empirical research, validated and demonstrated in practice) for centres that is hitherto non-existent in the knowledge domain. In fact, many end-users, especially centre directors, are generally unware of the concept of an underpinning business model for a centre.

A business model is the vehicle for delivering on the business strategy, i.e. the destination (vision) for the centre) with goals, objectives and milestones, and which is set by the centre's leadership and management team. They are the drivers of the strategy and charged with implementing the objectives of the strategy, which is endorsed by the stakeholders of the centre, i.e. the industry participants and the host university, and in some instances the government.

The implementation of the strategy, typically documented in a business plan, is funded (fuelled) by the stakeholders of the centre. Additionally, the host university provides the safety net (insurance) for the centre, i.e. financial underwriting responsibility for the centre being within the university, because a centre is not a separate legal entity but an integrated part of the host university. Therefore, it is in the best interests of all stakeholders and centre leaders to ensure that a robust recommended business model (demonstrated in the field, validated and underpinned by empirical research) is utilised as a starting point and which can be configured to minimise risk, as well as optimising the opportunity for the centre to be successful. However, the success of a centre is as the stakeholders define it through the strategy that they develop for the unique identity of the centre for the industry it serves.

Ultimately, the success of a centre requires the leaders to drive it, the business model to underpin it and the strategy to set the vision, goals and objectives for the centre, and subsequently the implementation plan to execute the strategy and track the progress of the centre against the set objectives.

There are six main groups of end-users for this research output. They are: (1) centre directors and centre managers (current and prospective); (2) university senior management; (3) university business development managers; (4) industry advisory boards for S&T centres within universities; and (5) managers in government science and innovation funding agencies; in addition to (6) consulting firms that could adopt the framework of the business model to conduct audits of university research centres.

6.3 RECOMMENDATIONS FOR FUTURE RESEARCH

The recommended model that has been developed could potentially be generalised globally, because in principle it is fundamentally a business model which can be configured to suit any university-hosted centre (i.e. using the 4D analysis and the WTG configuration). However, there is scope for future research, as it has only been validated and demonstrated in ANZ. Future research could test the feasibility of the model internationally.

There is also scope for future work to determine the weightings for the indices and the overall Centre Viability Index (CVI). However, once the weightings for the indices have been validated through academic rigour, the CVI could be combined with the model as a complete toolkit for the business model development of centres within universities.

The business model with the weighted indices has the potential to be converted into a niche software application for use in universities for establishing the business model for centres and for auditing centre viability within universities in general, in terms of centre structure, interactions, finance and activity, i.e. the four dimensions of the recommended model.

6.4 RECOMMENDATIONS FOR PRACTITIONERS

The recommended model can be utilised by university senior managers in charge of making policy and driving incentives for IA centre formation and monitoring outcomes; by centre directors and managers who have the challenges of forming, developing, operating and making centres self-sustainable; and by business development professionals charged with IA collaboration and supporting centre formation.

The recommended model can be adopted by universities in ANZ as a framework for centre formation and for improving existing centres, through being able to highlight opportunities for improvement, which in turn will enable existing centres to adapt. The model can also be utilised as a tool for cross-comparing centres within universities.

6.5 IMPACT FROM THIS RESEARCH

The major value from the original contribution of this research will be for new IA S&T collaborative centres that are likely to be spawned within ANZ universities over the next decade or more, where the recommended business model will pave the way for these centres to have viable foundations at the outset, a business model which is currently non-existent.

Centres that adopt the recommended business model are likely to achieve the following outcomes:

- There will be an adaptable value proposition to industry and university stakeholders, as well as government. Ultimately, the viability of a centre is determined by the value it delivers to its stakeholders in industry, the university and government.
- Centres will be resilient to changes in operating conditions in ANZ, given their ability to drive activities between the research, education and industry interaction domains, i.e. REI activity, which can be held in equilibrium based on the needs and wants of the stakeholders.
- The value proposition to industry partners can be levered under a CSR and/or an R&D banner.
- Academic participation in the centre will be enhanced, because there will be access to a greater array of IA collaborative projects, research grants and also research publications due to the involvement and support of hybrid academics employed by the centre.
- University stakeholders will be encouraged by the financial stability of the centres and their ability to draw in and sustain industry partners.
- University hosts will also receive value-adding from the centre's activities across the three REI portfolios, because REI activity leads to social and economic impact, which is a key priority for universities transitioning to entrepreneurial universities in addition to research and education impact, as evidenced by the mission statements and strategic plans of ANZ universities.
- Outputs generated via centre collaborations with industry will lead to new, highly skilled jobs which represent opportunities for graduates, and investment for research developed at the university that leads to commercialisation, both key areas of interest to the Australian (federal and state) and NZ governments.

- From a government perspective, a centre that leads to job creation, greater IA engagement, investments in innovation and research commercialisation (leveraging ANZ's strong research capability) is in synergy with the goals set by government. Government will come to the realisation that IA centres are a key vehicle and, if done to scale and volume in terms of encouraging more centres in universities, then these are likely to contribute to changing the overall OECD statistics for ANZ for poor IA collaboration, poor B2B collaboration and poor research translation.
- Overall, the success of IA collaborative centres in ANZ universities can play a key role in the transition of ANZ into the knowledge economy as a primary driver and, to do this, the centres need a business model framework that has been customised and validated for ANZ. This is the lasting legacy of this project and its contribution to ANZ.

Furthermore, given that the ANZ transition to the KE is underway and research universities are transforming into entrepreneurial universities, the emergence of IA collaborative centres is going to be a growing trend in ANZ universities and globally.

"The value of an idea lies in the using of it" – Thomas Alva Edison

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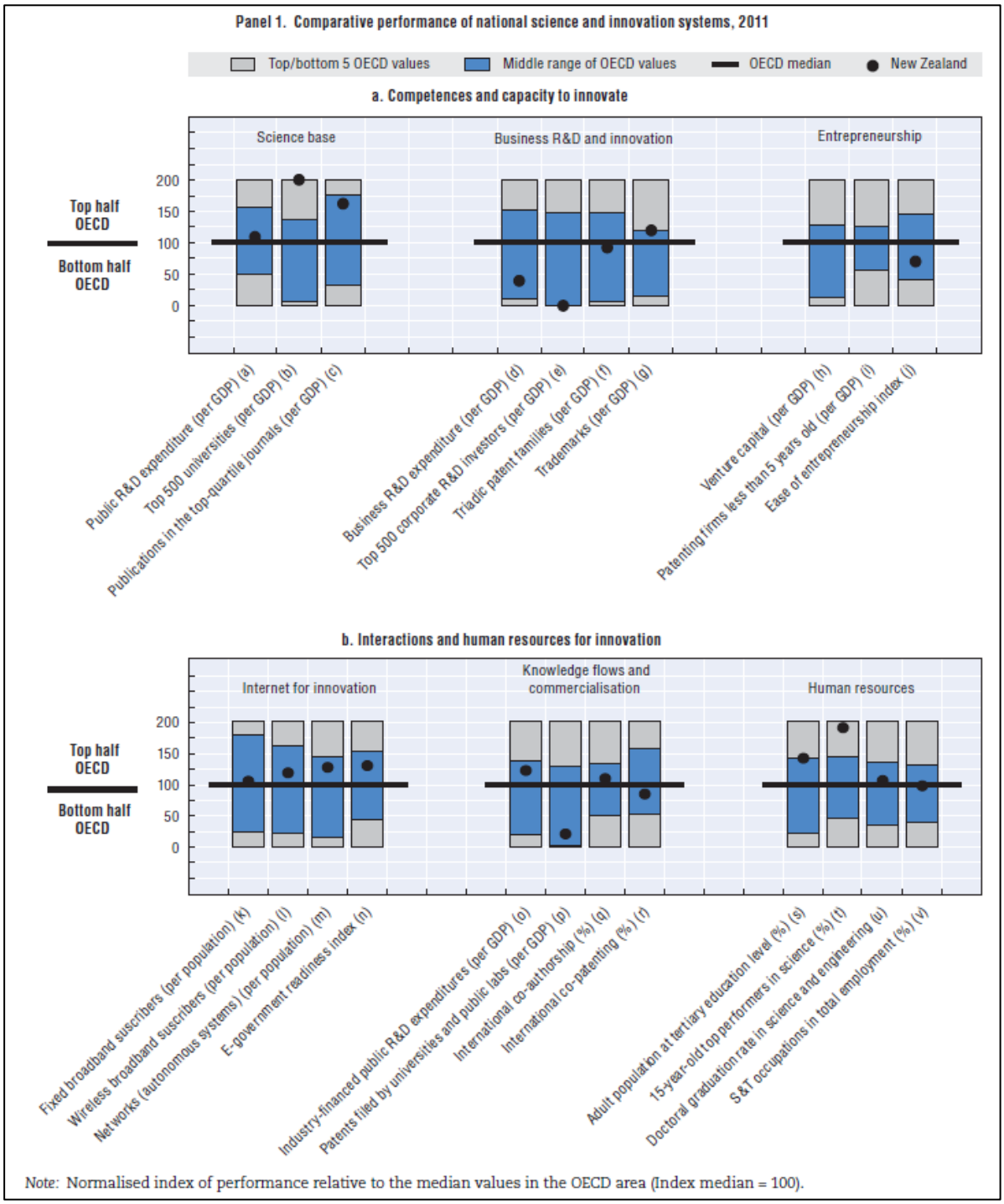
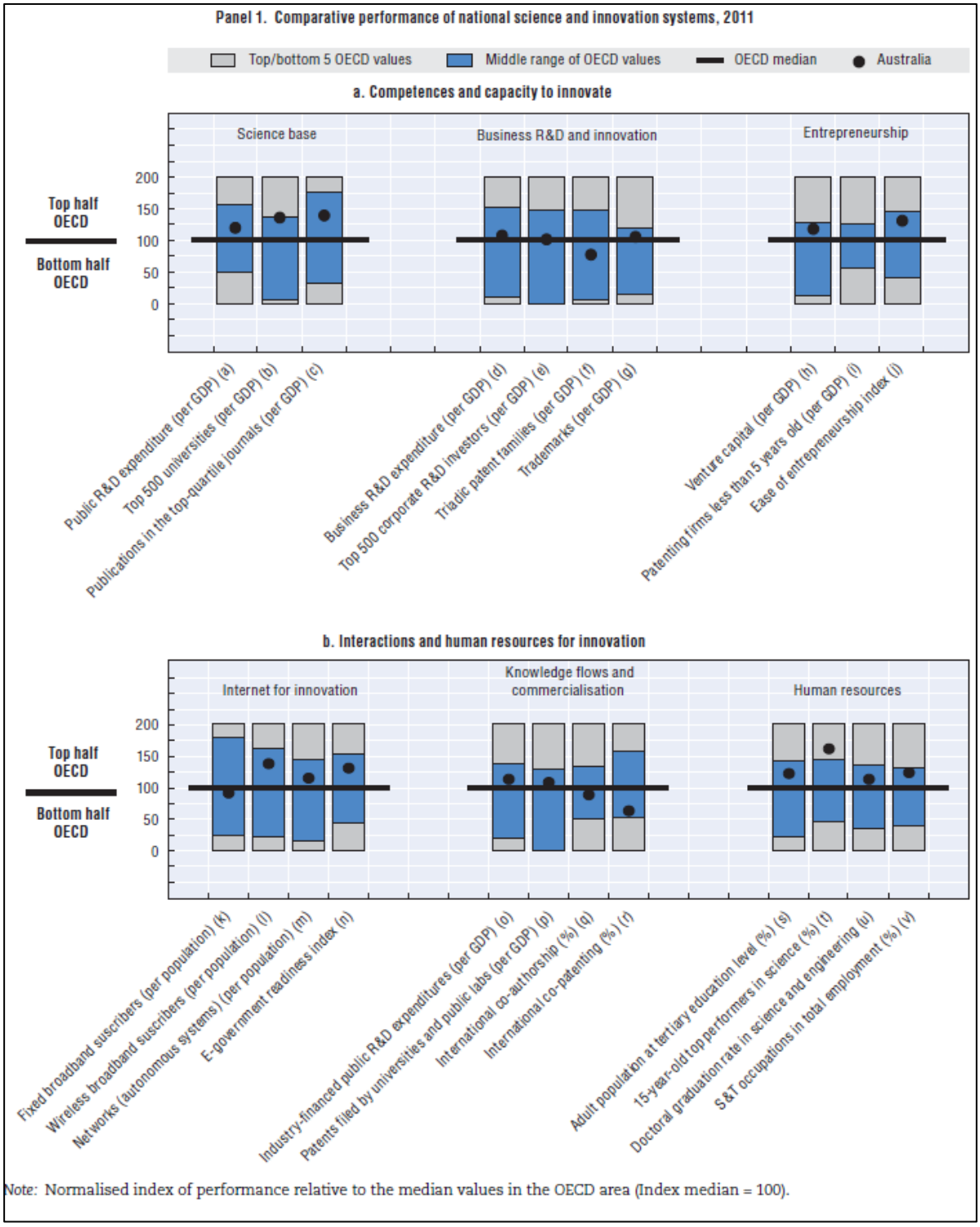
APPENDIX A – QUANTITATIVE DATA ANALYSIS

The OECD science and innovation country performance comparisons for 2012, between New Zealand[96] (*below*) and Australia [97] (*overleaf*), with key indicators such as science base, business R&D and innovation, entrepreneurship, and knowledge flows and commercialisation:



[96] Source: http://www.oecd.org/australia/sti-outlook-2012-new-zealand.pdf
[97] Source: http://www.oecd.org/australia/sti-outlook-2012-australia.pdf



Note: Normalised index of performance relative to the median values in the OECD area (Index median = 100).

Summary of key quantitative data collected for the field-site universities and the calculations for the ANZ university population (raw data sourced from publicly available and/or non-confidential sources: websites, annual reports, documents: University of Canterbury, Macquarie University, and Monash University).

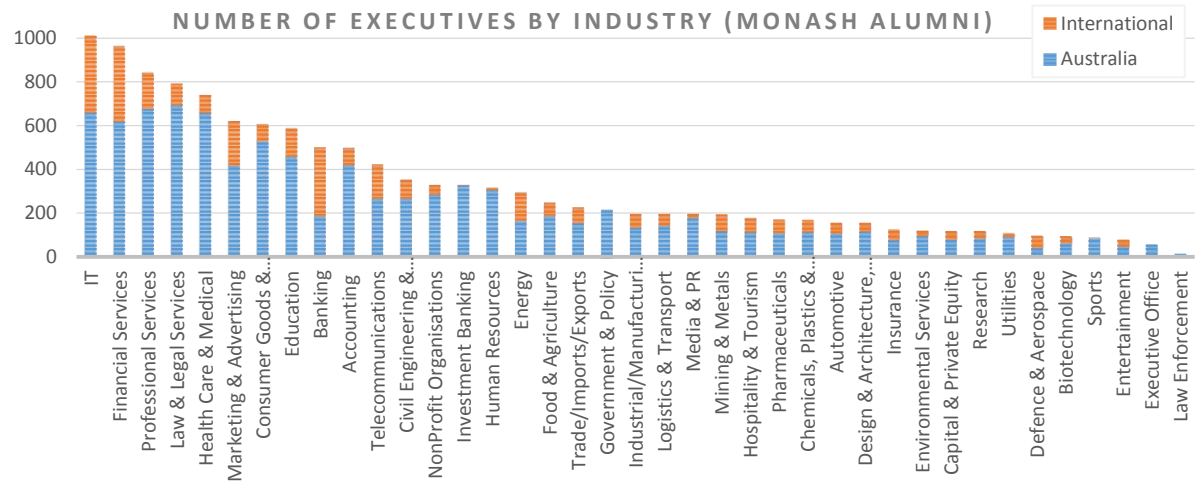
2016 Estimates	University of Canterbury	Macquarie University	Monash University	Average (μ) per ANZ university with sample standard deviation (σ)[98], where applicable	Total in ANZ (50) universities ~approx. projection
Established	1873	1964	1958	μ=1932	-
Age	143 years	52 years	58 years	μ=84 years; σ= 51	-
#Alumni in executive roles	*(19.38% of 14,725)* = 2,854^ *^Based on Monash's 19.38%*	*(19.38% of 38,747)* = 7,509^ *^Based on Monash's 19.38%*	~13,000[99] *(13,000 as a % of Monash's 67,067 student population is 19.38%)*	-	-
Student #s **(i.e. size of the university)**	14,725 (Medium)	38,747 (Large)	67,067 (Extra Large)	μ= 40,180 σ=26,200	2,008,983
Academic staff #s	726	1,457	2,549	μ= 1,577; σ= 917	78,850
Non-Academic staff #s	1,160	2,978	3,841	μ= 2,660; σ=1,368	133,000
Total staff #s	1,886	4,435	6,390	μ= 4,237; σ= 2,258	211,850
BDM/TTO (Technology Transfer Office) staff #s	5	5	30	μ= 13; σ= 14	650
Departments /Schools #s	42	35	51	μ= 43; σ= 8	-
Faculty /College #s	5	5	9	μ= 6; σ= 2	-
# of Academic staff per BDM/TTO staff member (ratio)	145 : 1	291 : 1	85 : 1	173 : 1 (academics to BDM/TTO staff ratio) per university	-
# of Centres (all types incl. non-S&T)	38	78	236	μ= 117 per university; σ= 105	5,850
# of S&T Centres (estimate)	27% of 38 = 10	27% of 78 = 21	64	μ= 32 per university; σ= 29	1,600
% of S&T Centres in ANZ universities	-	-	64/236 x 100 = 27%	32/117 x 100 = 27%	1,600/5,850 x 100 = 27%
Total # of ARC and TEC S&T Centres in ANZ	-	-	-	-	102 centres

[98] Source: https://statistics.laerd.com/statistical-guides/measures-of-spread-standard-deviation.php

[99] Source: https://au.linkedin.com/; using *search filters for School (Monash) with Seniority Level(VP, CEO, Partner, Owner)*

% of ARC and TEC S&T Centres in ANZ university S&T Centres	-	-	-	-	102/1,600 x 100 = 6%
Total # of non-ARC or TEC S&T Centres in ANZ	-	-	-	-	1,498
% of non-ARC or TEC S&T Centres in ANZ universities	-	-	-	-	1,498/1,600 x 100 = 94%
# of Public ANZ universities	-	-	-	-	47 out of 50; 94%
# of Private ANZ Universities	-	-	-	-	3 out of 50; 6%

The number of Monash University alumni in executive roles is shown below, ranging by industry sector and location (local or international). The raw data was sourced through LinkedIn in December 2015.



Number of Executives (Vice Presidents, Partners and Chief Executives) by industry, worldwide (Monash Alumni); modified from data sourced via LinkedIn.[100]

[100] Source: https://au.linkedin.com/; using *search filters for School (Monash) with Seniority Level(VP, CEO, Partner, Owner)*

APPENDIX B – OBSERVATIONS & VALIDATION INTERVIEWS

CASE STUDIES AND/OR BROAD OBSERVATION HIGHLIGHTS AT THE ANZ FIELD-SITE UNIVERSITIES

University of Canterbury (2005–2011), New Zealand	▪ Electric Power Engineering Centre (EPECentre)
Macquarie University (2011–2012), New South Wales, Australia	▪ Ancient Mediterranean studies program ▪ Macquarie Cancer Research Institute ~ early stage ▪ ANZAC research program ~ explorative
Monash University (2012–2016), Victoria, Australia	▪ Victorian Centre for Sustainable Chemical Manufacturing (VCSCM) ▪ Australian Centre of Excellence for Electromaterials Science (ACES) spinout of AquaHydrex ▪ Monash Academy for Cross & Interdisciplinary Mathematical Applications (MAXIMA) ▪ Monash Centre for Atomically Thin Materials (MCATM) ▪ Chemicals and Plastics Manufacturing Innovation Network and Training Program (C&P Innovation Program) ▪ Centre for Resource Science and Technology (*CReST*) *** under development *** ▪ Perkin Elmer Flagship ▪ Axieo Centre for Innovation ▪ Monash Energy Materials and Systems Institute (MEMSI) ▪ Green Chemical Futures Industrial Innovation Institute (GCF I^3) ▪ Monash Food Innovation Centre (FIC) *** under development *** ▪ Regenerative Medicine Industry Interface (RMI^2) *** under development *** ▪ GE Innovation Hub *** under development *** ▪ ….

WTG MODEL VALIDATION AND PERSPECTIVES – INTERVIEWS February–April 2016

Interviewee:*	**Perspective of the Interviewee:**
Distinguished Professor	UNIVERSITY
Head of Department/Professor	UNIVERSITY
IA Centre Director/Professor	UNIVERSITY
Institute Deputy-Director/Researcher	UNIVERSITY
Industry Professor / IA Centre Director /Industry R&D Director	UNIVERSITY/INDUSTRY
Senior Manager - Government	GOVERNMENT
Industry Executive with IAB experience	INDUSTRY
Industry Chief Executive / IAB Chair for an IA Centre	INDUSTRY
Senior Executive – Government with IAB experience	GOVERNMENT/INDUSTRY

**Note: Names are confidential*

APPENDIX C – QUALITATIVE: GROUNDED THEORY CODES

Codes and themes derived from modified Grounded Theory (GT) approach: Based on EPECentre longitudinal case study, followed by field-site observations and analysis of documents, data.

Codes from Initial Coding results from modified Ground Theory: qualitative data from field-site observations (2005-2016) and EPECentre longitudinal case study (2005–2011)	*Categories / Themes (post Axial Coding)*
i. Entrepreneurship *ii. Intrepreneurship vs. risk adverse management* *iii. Managing clever people* *iv. University culture* *v. Empowerment & trust* *vi. Freedom* *vii. Flexibility* *viii. Agility/nimble/Responsive* *ix. Strategy (EPECentre approach and template)* *x. Risk management (e.g. Plan B)* *xi. Culture* *xii. operations* *xiii. Business plans* *xiv. Management culture in ANZ* *xv. Project management* *xvi. Bold initiatives* *xvii. Risk taking* *xviii. Humble vs boastful* *xix. Centre directors and managers* *xx. Reporting lines (also touch in within university arrangements)*	*(a) Leadership and Operations of a Centre*
i. Governance *ii. Industry Advisory Board* *iii. Industry led* *iv. Industry Chair vs Independent Chair (antithesis)* *v. Alumni* *vi. Accessing Networks* *vii. Inclusion of University reps*	*(b) Centre Governance*
i. Universities in ANZ vs global universities (private vs public) *ii. University competition* *iii. Culture* *iv. Overheads and space* *v. Reporting lines* *vi. Block grant funding* *vii. Research university vs. entrepreneurial university (antithesis)* *viii. KPIs in a research university (research & teaching)* *ix. KPIs in an entrepreneurial university (knowledge transfer, industry engagement)* *x. Academic culture* *xi. Fundamental vs applied research* *xii. Key internal stakeholders* *xiii. Obsession with global vs national* *xiv. Academic salaries* *xv. View on consulting / consulting practice* *xvi. Buying people out (from teaching, research and administration)* *xvii. Academic promotion* *xviii. Contract lecturers (why not get it from practice professors/quasi academics instead)* *xix. Funding: education, research and commercial (consulting, rental)* *xx. IP / Commercialisation* *xxi. Rankings* *xxii. Metrics in university PBRF, ERA*	*(c) University Hosting*
i. Brand *ii. Lobbying* *iii. Partnership vs collaboration* *iv. Membership* *v. Interaction*	*(d) Centre collaboration with*

vi.	Trusted relationship	*industry: membership*
vii.	Levels of contacts	
viii.	Decision makers vs technical managers	
ix.	Snow ball	
x.	Consortia	
xi.	Management culture in ANZ (surveys)	
xii.	Market pull vs technology push	
xiii.	Sponsorship	
xiv.	Value proposition	
xv.	The pitch	
xvi.	The hook	
xvii.	CSR	
xviii.	Training and upskilling	
xix.	IP and confidentiality	
xx.	Consulting	
xxi.	Industry events	
xxii.	Philanthropy	
xxiii.	Incentives (CRS, tax credits)	
xxiv.	R&D tax credits	
xxv.	Outcomes	
xxvi.	B2B and B2C	
xxvii.	Funding research	
xxviii.	Motivation to engage with a university	
xxix.	Recruitment	
xxx.	Leveraging	
xxxi.	Sustainability	
xxxii.	Business models	
xxxiii.	Government interaction	
xxxiv.	Time and resource commitment	
xxxv.	Resource allocation for collaboration	
xxxvi.	End to end /value chain	
xxxvii.	Global access	
xxxviii.	Differentiation	
xxxix.	Collaboration vs competition	
xl.	Statistics on collaboration	
xli.	Collaboration in ANZ	
i.	Knowledge Economy impact	*(e) Centre Activities*
ii.	Research	
iii.	Commercialisation	
iv.	Knowledge transfer	
v.	Education	
vi.	Outreach	
vii.	Innovation	
viii.	Marketing and PR, COMMS	
ix.	Alumni	
x.	Networking	
xi.	Shopfront	
xii.	Scholarships	
xiii.	Events	
xiv.	Portfolio approach	
xv.	Research themes	
xvi.	Workshops/conferences	
xvii.	Seminars	
xviii.	Committees	
xix.	Field trips	
xx.	Consulting	
xxi.	Research	
xxii.	Publication	
xxiii.	Media	
xxiv.	Recruitment	
xxv.	Pipeline	
xxvi.	Careers	
xxvii.	Expos	
xxviii.	Impact	
xxix.	Funding	
xxx.	Contracts	
xxxi.	Deliverables	
xxxii.	KPIs	
xxxiii.	Books / guidelines	
xxxiv.	R&D projects	

xxxv.	*Demonstrations*	
xxxvi.	*Advertising*	
xxxvii.	*Stem*	
xxxviii.	*Graduates - Quantity and quality*	
i.	*2nd class citizenship (academic vs non-academic)*	*(f) Centre Staff and People*
ii.	*Pseudo academics / industry practice professors*	
iii.	*Research groups*	
iv.	*Employment contracts (soft money/underwritten staff)*	
v.	*Team work*	
vi.	*Casual staff and interns*	
vii.	*Postdocs and PhD students*	
viii.	*Sharing credit*	
ix.	*Complementary skills (multidisciplinary)*	
x.	*Remuneration (university rates vs market rates)*	
xi.	*Research associates (internal vs external)*	
xii.	*Reporting lines*	
xiii.	*Team culture*	
xiv.	*Talent*	
xv.	*Capability statements*	
xvi.	*Team leadership*	
xvii.	*mentoring*	
xviii.	*meetings*	
xix.	*Optimal team structure*	
xx.	*Infrastructure*	
xxi.	*Incentives/KPIs*	
xxii.	*Recognition*	
xxiii.	*Promotion*	
i.	*Centre models*	*(g) Centre Models*
ii.	*Industry and university*	
iii.	*Government and university*	
iv.	*Types in ANZ vs international*	
v.	*Funding for centres*	
vi.	*Focus areas for centres (typically research)*	
vii.	*Funding period for centres*	
viii.	*What does success look like*	
i.	*ANZ*	*(h) Australia and NZ (ANZ)*
ii.	*The economy*	
iii.	*Industry in ANZ*	
iv.	*Governments in ANZ*	
v.	*Society and culture*	
vi.	*GPD*	
vii.	*R&D spending*	
viii.	*Commercialisation of research*	
ix.	*Venture capital*	
x.	*Environment*	
xi.	*Geography*	
xii.	*Big industry sectors –growth centres*	
xiii.	*International education*	
xiv.	*Demographics*	

APPENDIX D – MULTIDIMENTIONAL WEIGHTED INDICES

This section shows how the findings of the research (Chapter 4) with the 4Ds (Figure 41) is integrated to produce a multidimensional weighted index (Decancq & Ana Lugo, 2013; Fernandes, et al., 2013). "Multidimensional indices are becoming increasingly important instruments to assess the wellbeing of societies" (Decancq & Ana Lugo, 2013, p. 7). This equally applies to IA centres, because of the complexities involved for such a boundary-spanning entity, i.e. between industry, university and government, within the 4Ds (Figure 41).

The centre viability index takes the 4Ds as an input and translates each dimension into a quantitative score, which in turn is converted to a weighted index for each dimension.

However, an important step in the process of developing an overarching index is the selection of the relative weights for each of the four dimensions (4Ds). Weighting schemes for multidimensional indices are typically applied based on reasonability with respect to trade-offs between the various dimensions (Decancq & Ana Lugo, 2013; Fernandes, et al., 2013). However, there is no widely accepted framework for determining these trade-offs (Decancq & Ana Lugo, 2013). Therefore, a researcher is required to use judgement and underpin the rationale with research data where possible, i.e. use common sense (Decancq & Ana Lugo, 2013).

In this case, the multidimensional indices were derived through the findings from the research (Chapter 4) and the weightings were applied based on the professional judgement of the researcher (Decancq & Ana Lugo, 2013), as per the relative importance observed for various elements throughout the research process in each of the field-site ANZ universities and the longitudinal EPECentre case analysis. The researcher was an observer-participant conducting insider-led research.

The weightings applied to each of the 4Ds were as follows: 30% (structural index), 10% (functional index), 50% (financial index, defined by revenue rather than expenditure) and 10% (activity index). Once the preliminary weighted indices were calculated for each of the 4Ds (multidimensions), an index correction factor of 0.1 was applied to each, i.e. each of the preliminary weighted indices was subtracted by 0.1 to compensate for any biases or uncertainties within the weighted index. Furthermore, once the preliminary calculation was made for the overall weighted centre viability index, another 0.1 index correction was applied. This allowed for a conservative viability index that reflects the real world.

Furthermore, a sensitivity analysis was carried out to determine the robustness of the multidimensional weighted index.

The ideal recommended model for an IA centre in an ANZ university is one which scores 0.8 on the viability index and achieves the highest points for the indices in all the four dimensions (4Ds). The ideal model is described following the details of the indices and the calculation of the viability index.

The Structural Weighted Index

Figure 53 shows the structural weighted index for the structure dimension.

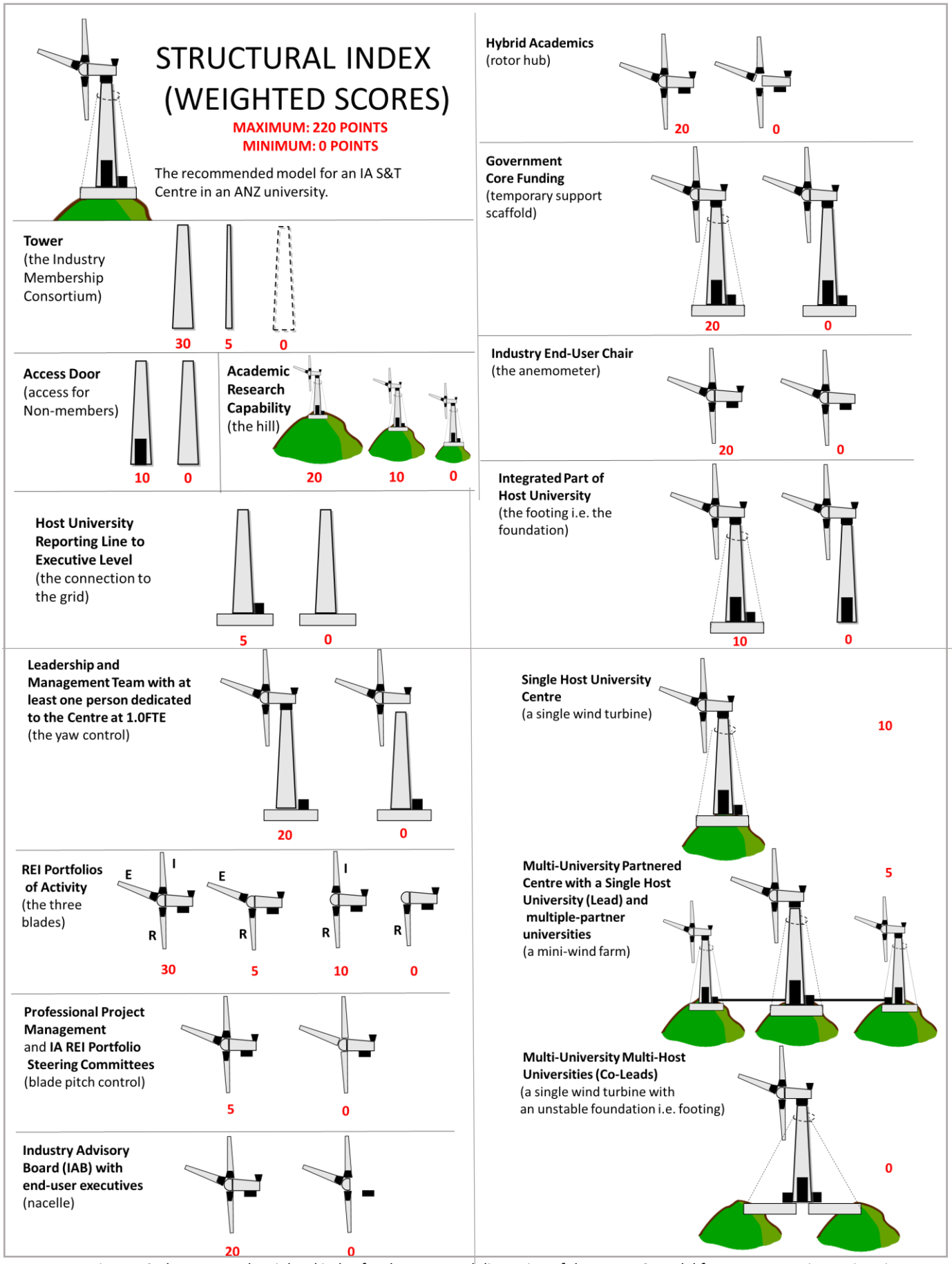


Figure 53 The structural weighted index for the structural dimension of the 4D WTG model for an IA centre in a university.

The Interactional Weighted Index

Figure 54 shows the interactional weighted index for the interaction dimension.

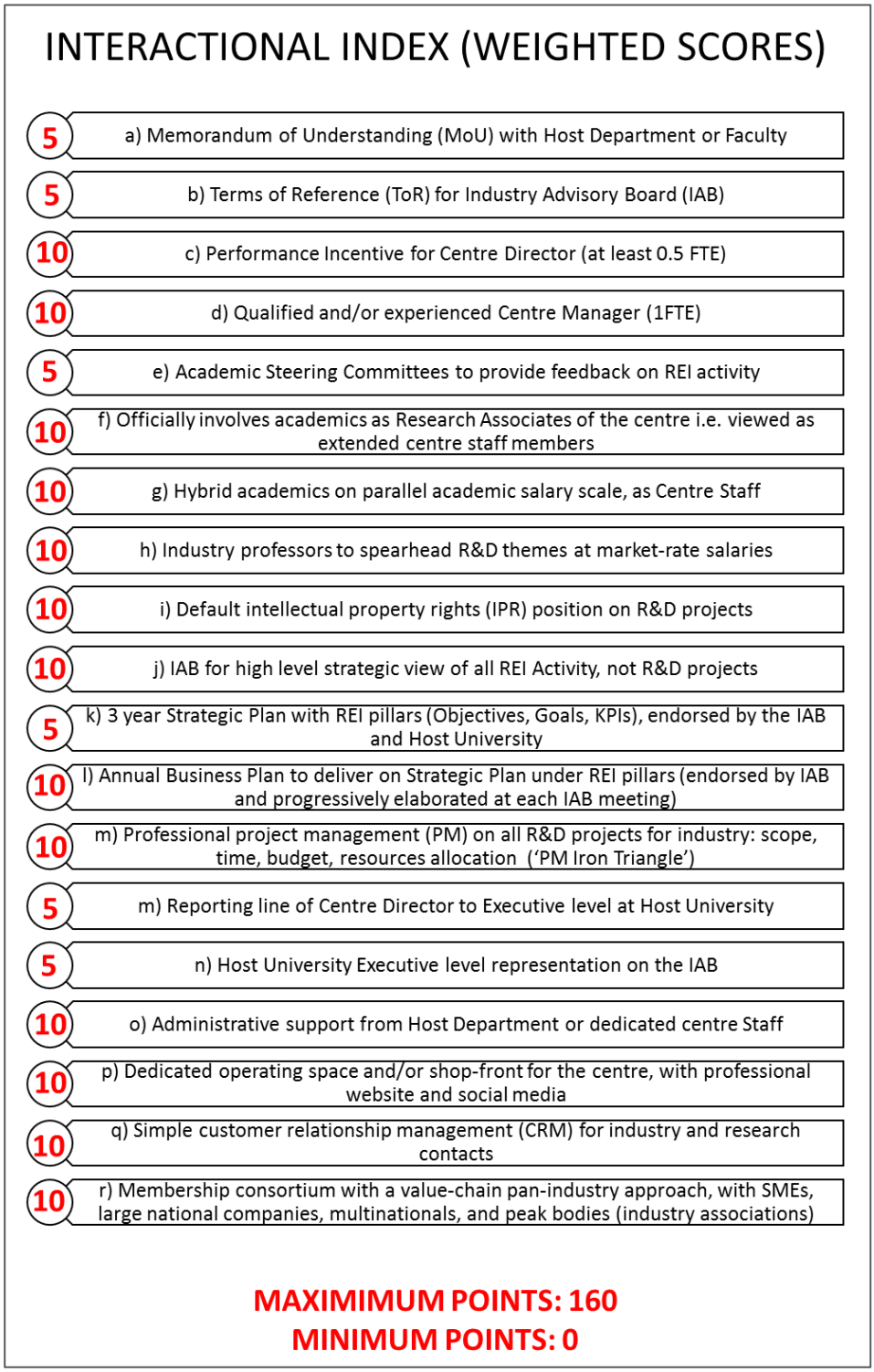


Figure 54 The interactional weighted index for the interaction dimension of the 4D WTG model for an IA centre in a university.

The Financial (Revenue) Weighted Index

Figure 55 shows the financial (revenue) weighted index for the finance dimension.

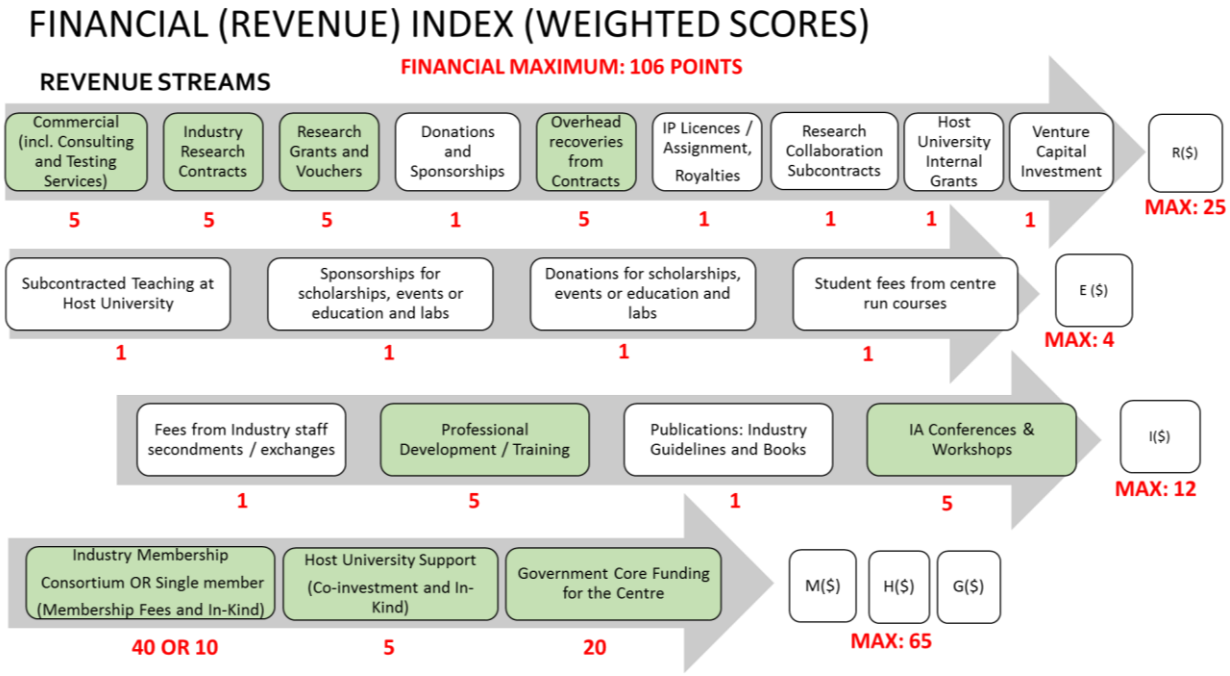


Figure 55 The financial (revenue) weighted index for the financial dimension of the 4D WTG model for an IA centre in a university.

The Activity Weighted Index

Figure 56 shows the activity weighted index for the activity dimension.

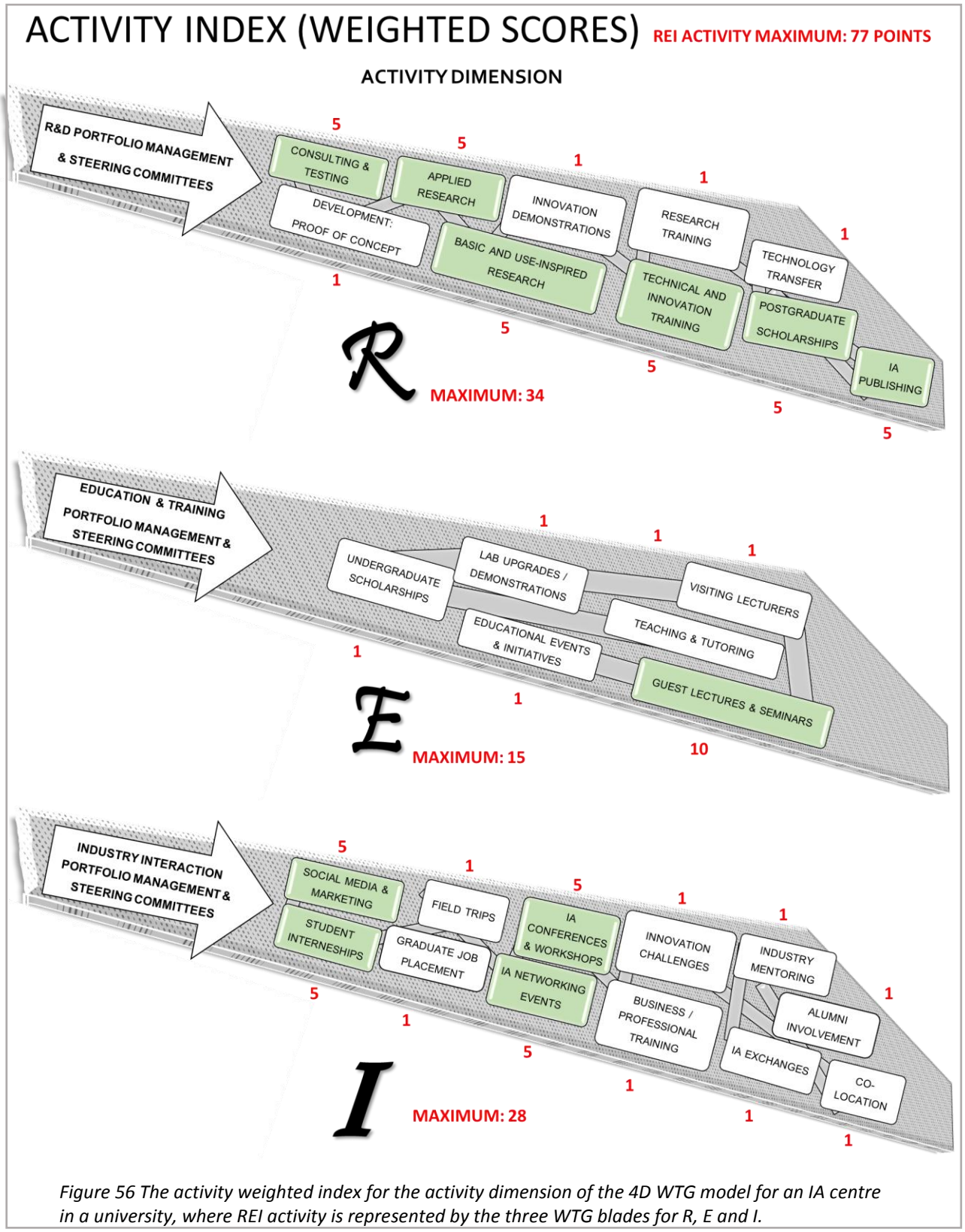


Figure 56 The activity weighted index for the activity dimension of the 4D WTG model for an IA centre in a university, where REI activity is represented by the three WTG blades for R, E and I.

The multidimensional weighted index, as per weightings described earlier (section 5.4), allocated the following weightings to the 4Ds (Figure 41) of structure, function, finance and activity, in order to define the Centre Viability Index (CVI):

$$Centre\ Viability\ Index = ((Structural\ Index * 0.9 * 0.3) + (Interactional\ Index * 0.9 * 0.1) + (Financial\ Index * 0.9 * 0.5) + (Activity\ Index * 0.9 * 0.1))*0.9$$

Where 0.1 is the index correction at two levels, to compensate for uncertainty and bias. The recommended model for ANZ is the ideal, and it scores the maximum possible on indices on all the 4Ds (0.9 for all) and the maximum possible CVI of 0.81; where 90% weightings have been assumed and applied at each step to allow for uncertainty (for the purposes of this calculation).

For example, with the EPECentre at the University of Canterbury, the multidimensional indices for the 4Ds are:

- structural index x 0.9 = 0.82
- interactional index x 0.9 = 0.76
- financial index x 0.9 = 0.68
- activity index x 0.9 = 0.88

The calculation is as follows: ((0.82*0.3) + (0.76*0.1) + (0.68*0.1) + (0.88*0.5)) * 0.9 = 0.68

Therefore, the Centre Viability Index (CVI): 0.68, where a CVI ≥ 0.50 is deemed viable (assumed).

This results in the Centre Viability Index (CVI) scoreboard that is shown in Figure 57 and the Centre Viability Index Checklist for improvement shown in Figure 58. Together, the scorecard and the checklist for improvements can be used to cross-compare the test sample with the recommended model for an S&T IA centre within an ANZ university, and to consider improvements as recommended by the scorecard and checklist for improvements. This was repeated for a total of 10 centres as a means of testing the CVI, which was found to be accurate, with the weighting choices requiring further academic rigour and justification for validation.

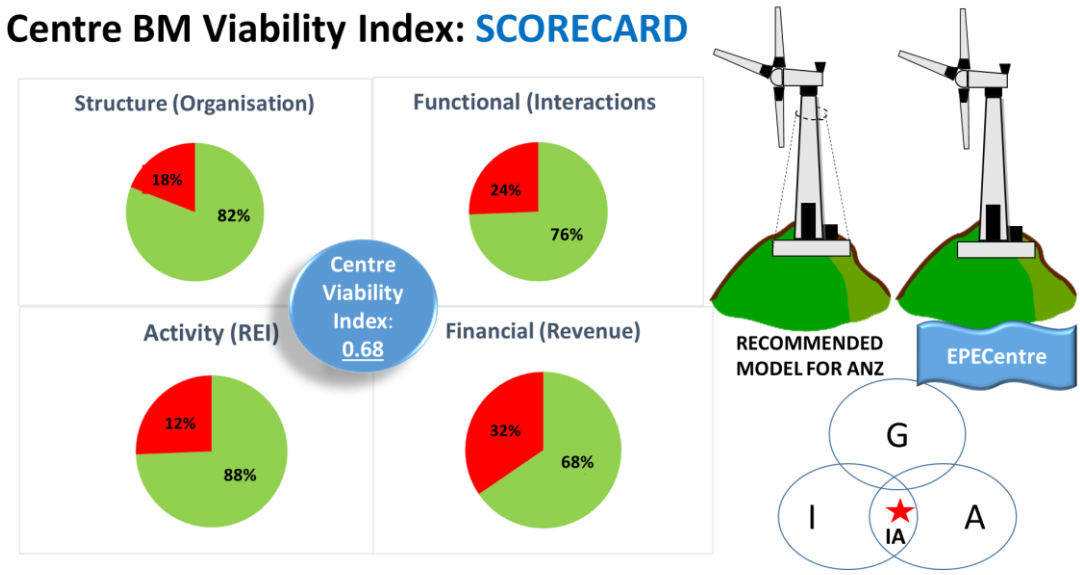


Figure 57 The Centre Viability Index (CVI) scorecard, with respect to the recommended S&T IA centre model for ANZ universities in each of the four dimensions, underpinned by the research findings (Chapter 4). The recommended model is shown next to the test sample, to compare structural configuration differences.

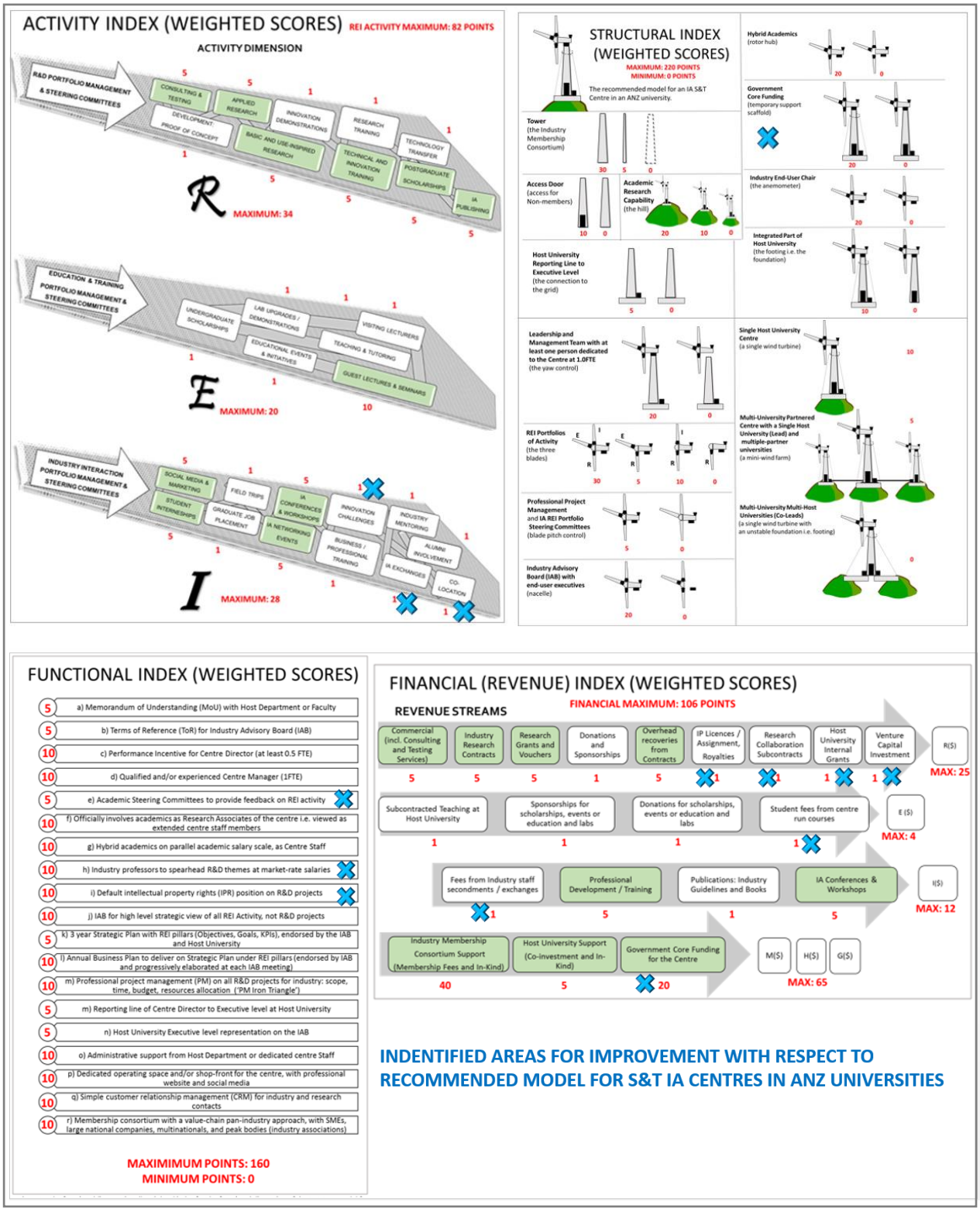


Figure 58 The Centre Viability Index (CVI) scorecard checklist for improvements, compared to the recommended S&T IA centre model for ANZ universities, underpinned by the research findings (Chapter 4).

Based on Figure 57 , for the EPECentre sample exercise, a CVI of 0.68 on the scorecard indicates that the centre is viable, since the CVI is greater than 0.50. Also, from the scorecard, it achieves a score of 82% for structure, which reflects on its organisational structural dimension, 76% for its interactions

(internal and external), 88% for its REI activities that delivers KE impact, and 68% for its financial (revenue) dimension. The WTG model image has a slight variance to the ideal ANZ model. EPECentre does not have the temporary scaffold, which represents core government funding for the centre.

The CVI checklist for improvement

Figure 58 indicates the areas for improvement, identified by the 'blue X'. According to the checklist for improvement for the EPECentre, in the:

- structure dimension, the EPECentre could consider:
    a) core government funding in order to improve its viability

- interaction dimension, the EPECentre could consider adopting, in no specific order:
    a) academic steering committees to provide feedback on REI activity
    b) industry professors to spearhead R&D themes at market-rate salaries
    c) default intellectual property rights (IPR) position on R&D projects

- finance dimension, the EPECentre could consider exploring revenue from:
    a) IP licences/IP assignments and royalties.
    b) subcontracts with other universities (locally and internationally) on research programs.
    c) consider applying for host university internal research grants, where possible.
    d) consider avenues for venture capital funding for R&D projects.

- activity dimension, the EPECentre could consider:
    a) conducting innovation challenges with industry, students, and staff.
    b) IA staff exchanges and secondments (local and international).
    c) co-location or embedding industry R&D teams or personnel.

The EPECentre example demonstrates the utility of the CVI and how it can be used as a tool for the cross comparison of centres and for improvements. The EPECentre in practice has proven to be a viable model and has been in operation since 2002. The CVI tool would be of practical value to any new centres being developed at ANZ universities, and perhaps international universities.

THE LIMITATIONS OF THE CVI AND MODEL

- It is based on underpinning research based in ANZ for the CVI has not been validated with centres in other countries. However, the international usability of the CVI was outside the scope of this project. There is scope for future work in determining the feasibility of the CVI internationally.
- Any person utilising the CVI is required to have some background or have the opportunity to liaise with appropriate centre directors, managers, participants or stakeholders to get an accurate CVI output. However, this should not be an issue, because the CVI tool is aimed at ANZ universities, which have the necessary level of background.
- The CVI tool takes approximately 60 minutes to produce a result. However, without sufficient background on the centre being analysed, this could take longer.
- There is no comparative model or tool in the literature (Chapter 2), with various classifications and typologies (section 2.11), or in practice for the development of business models for centres in universities. Furthermore, the rigour of the model is its grounding or underpinning on empirical research results (Chapter 4). Hence, this is an original contribution to the knowledge domain.